



THE  
ORIGINAL  
AND  
LARGEST  
**ZINC OXIDE**  
PRODUCERS  
IN  
THE UNITED KINGDOM

*Samples and quotations on application to*

**FRICKER'S METAL CO.**

Limited

**Norfolk House, Laurence Pountney Hill**

**LONDON, E.C.4**

Telephone: 4887 CITY

Telegraphic Address: "OXYPOWDER, CANNON, LONDON"

**WORKS: LUTON, BEDS.**

*By mentioning this book when replying, you will oblige  
Advertiser, Author, and Publishers*

# *Glaxo* **WHITE**

*The FINEST  
Turpentine  
Substitute*

# *SPIRIT*

Wholesale and Retail Dealers, or nearest persons to whom orders may be sent, will be glad to supply the same on application to the nearest office in all the leading towns of the United Kingdom.

## **THE GAS LIGHTING IMPROVEMENT Co., Ltd.**

**15, ABchurch HOUSE, QUEEN SQ., W.C.**

MANUFACTURERS OF ALL KINDS OF GAS APPARATUS, INCLUDING GASOLINE ENGINES, AND ALL KINDS OF GAS AND WATER MACHINERY.

**THE RED HAND  
COMPOSITIONS LTD.**  
18 Billiter St., London, E.C.3

---

**ANTICORROSIVE  
& ANTIFOULING  
COMPOSITIONS**

c For Ships' Bottoms

**THE RED HAND BRAND**

---

**ANTICORROSIVE  
PAINT**

For Boottopping, Topsides, Holds, and General  
Ships' Work

---

*Contractors to the Admiralty. India Office, War  
Office, Crown Agents for the Colonies, etc., etc.*

---

Factory—SILVERTOWN, LONDON, E.

Branches at—

LIVERPOOL, GLASGOW,  
NEWCASTLE, CARDIFF,  
SOUTHAMPTON & ALEXANDRIA

---

Agencies and Stocks at all important Ports  
throughout the World

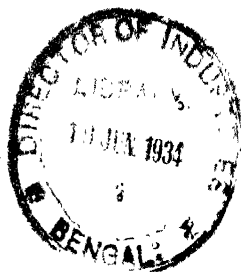
*By mentioning this book when replying, you will oblige  
Advertiser, Author, and Publishers*

# **PITMAN'S TECHNICAL PRIMER SERIES**

*Edited by R. E. NEADE, B.Sc., Hons. (Lond.)*

*A.C.C.I., A.M.I.E.E.*

**OILS, PIGMENTS, PAINTS,  
VARNISHES, ETC.**



# **PITMAN'S**

---

## **TECHNICAL PRIMERS.**

---

Edited by R. E. NEALE, B.Sc. (Hons.),  
A.C.G.I., A.M.I.E.E.

IN each book of the series the fundamental principles of some sub-division of technology are treated in a practical manner, providing the student with a handy survey of the particular branch of technology with which he is concerned. They should prove invaluable to the busy practical man who has not the time for more elaborate treatises.

Uniform with this volume,  
each **2s. 6d.** net

---

*For Complete List see end of book.*

# OILS, PIGMENTS, PAINTS, VARNISHES, ETC.

A CONCISE TREATISE ON THE MANUFACTURE,  
PROPERTIES, AND USES OF LIQUID PROTECTIVE  
AND DECORATIVE COATINGS AND THEIR  
INGREDIENTS

FOR STUDENTS AND ALL THOSE CONCERNED  
WITH THE MAKING OR  
APPLICATION OF THESE MATERIALS

BY

RUPERT H. TRUELOVE

B.Sc. (HONS.) LOND., A.R.C.S., F.I.C., F.C.S.



LONDON

SIR ISAAC PITMAN & SONS, LTD.  
PARKER STREET, KINGSWAY, W.C.2  
BATH, MELBOURNE, TORONTO, NEW YORK

1922

PRINTED IN BATH, ENGLAND  
BY SIR ISAAC PITMAN AND SONS, LTD

## PREFACE

NEARLY all objects, large or small, which are made or used by man have upon their surfaces a coating composed of materials different from those of the objects themselves. The purpose of this almost universal condition is either protective or decorative; protective, because it is a fact that the materials best fitted for the formation of an article or structure are seldom the best suited to resist the external destructive influences of weather, abrasion, etc.; decorative for the reason that man has an aesthetic sense and it is of distinct value to him in his life to be surrounded by objects which do not offend this sensibility.

The aim of this volume is to deal tersely yet comprehensively with the manufacture and use of coatings of the type which are applied in liquid form and afterwards solidify. This subject clearly includes those coatings of which linseed oil is the basis, and as they are by far the most widely used type at present, they receive a treatment proportionate to their importance.

In general, the manufacture or origin of the materials used in the liquid compositions is dealt with briefly, but their properties and mode of use are described more fully, with



special reference to the technical points concerned in the manufacture of the coating and in the question of the values and deficiencies of the finished articles from the point of view of the user.

The matter herein is not merely elementary. By dealing with the subject from the point of view of first principles, so far as it allows, the writer has endeavoured to present it so that it will be understood by many to whom the details of the subject are fresh, and will yet be of value to the Works' Staff. A short bibliography is included to assist further study.

The numbers in the text refer to paragraphs in the book in which will be found other matter relevant to that under discussion.

The author is indebted to Messrs. Follows & Bate, Ltd. (Manchester), for the loan of blocks illustrating grinding and mixing machines.

RUPERT H. TRUELOVE.

# CONTENTS

	PAGE
PREFACE . . . . .	V

## CHAPTER I

COATINGS FOR VARIOUS PURPOSES . . . . .	1
---	---

House painting Floors Factories Protection of iron and steel Furniture, small articles, etc. Submerged surfaces.

## CHAPTER II

LINSEED OIL AND DRYING-OIL VARNISHES . . . . .	8
--	---

Linseed oil Boiled oil—Stand oil—Laboratory work—Driers—Copal varnish—Turpentine—White spirit—Copals—Varnish plant Melting resin—Preparation of oil—Oiling-up Thinning varnish—Set-pot process—Adding driers to varnish Tanking varnishes Wood oil varnishes—Fung oil.

## CHAPTER III

DRYING-OIL PAINTS . . . . .	34
-----------------------------	----

Typical recipe—Oil for paints—Mixed pigments—Percentage and kind of oil Enamels Thickness of oil-paint film—Specifications—Importance of volumetric composition—Manufacture of oil paints.

## CHAPTER IV

PIGMENTS AND SOLID FILTERS . . . . .	53
--------------------------------------	----

General requirements—Physical characteristics—Zinc oxide—Lead zinc—Lithopone—Basic carbonate white lead—Basic sulphate of lead Antimony oxide and titanium oxide—Transparent fillers Barites—Blanc fixe China clay—Silica—Asbestos—Whiting—Terra alba—Drop black—Graphite—Oxides of iron—Umber—Ochre and sienna—Red lead—Yellow chrome—Zinc chrome—Prussian blue—Ultramarine blue—Brunswick greens—Chrome oxide green—Lakes.

	PAGE
CHAPTER V	
COATINGS WHICH DRY BY EVAPORATION OF	
SOLVENTS . . . . .	80
<i>Turpentine, White Spirit, Light Naphtha</i> -Resins used- Softeners--Manufacture of quick-drying paints -Short- oil varnish -Gold size -Fetichines--Uses of gold size - Substitutes for linseed oil. <i>Bituminous Coatings</i> -Petro- leum type -Coal tar type. <i>Alcoholic Varnishes</i> -Shellac - French polish -Soft Manila -Sandarac -Rosin. <i>Cellulose</i> <i>Varnishes</i> -Nitro-cellulose -Cellulose acetate. <i>Distempers</i> -Simple distemper -Casein -Washable distemper	
BIBLIOGRAPHY . . . . .	111
INDEX . . . . .	112

## ILLUSTRATIONS

FIG.	PAGE
1. •Effect of a Catalyst on the Drying of Linseed Oil . . . . .	14
2. Varnish Pot . . . . .	21
3. Polymerization Curve for Tung Oil . .	32
•4. Water-cooled Flat-stone Mill for Very Fine Grinding . . . . .	40
5. Vertical Pug Mill for Mixing Stiff Pastes.	46
6. Horizontal Pug Mill for Mixing Stiff Pastes	47
7. } Triple-roller Mill for Grinding Stiff Pastes	48, 19
8. }	
•9. Vertical Mixer for Final Thinning and Amalgamation of Paint . . . . .	50
10. Mixer for Finishing Paint . . . . .	50
11. } Cone Mill for Grinding Thin Paste and	
12. } Ready-mixed Paint . . . . .	51, 52
13. Edge-runner Mill. Rotating Pan Type .	54
14. • Iron Edge-runner Mill. Rotating Rollers.	55
15. Granite Edge-runner Mill. Rotating Rollers	56

## TABLES

I. • Comparison between Laboratory Pot and Large Works Pot . . . . .	13
II. Typical Specifications for Oil Paints .	44

	PAGE
III. Physical Characteristics of Typical Pigments . . . . .	45
IV. Refractive Indices, Illustrating Transparency and Opacity of Pigments . . . . .	63
V. Comparison between Linseed Oil Paint and Substitute Paint . . . . .	89
VI. Various Recipes for Cellulose Nitrate Varnishes . . . . .	102

# OILS, PIGMENTS, PAINTS, VARNISHES, ETC.

## CHAPTER I

### COATINGS FOR VARIOUS PURPOSES

THE nature of the coating for a surface varies widely according to (*a*) the nature of the surface to be coated, (*b*) the influences to which it is to be exposed, (*c*) the final appearance desired. Considerations (*a*) and (*b*) determine the nature and degree of *protection* to be provided, whilst (*c*) is of importance from the standpoint of *decoration*. Sometimes protection is subservient to appearance and sometimes appearance is of little account, but protection very important. As a general rule the need for protection need not prevent that for decoration being satisfied.

**1. House Painting.** For the decoration of those portions of buildings which lend themselves to this, oil paints and varnishes are almost exclusively used, both inside and out.

These consist of a "drying" oil, usually linseed oil (§ 7), with which a resin has been incorporated, to make a *varnish* (§ 12); or in which a pigment has been finely ground to make a *paint* (§ 26). Sometimes the paint contains a mixture of several oils, but linseed oil is nearly always the basis of the mixture; and sometimes the paint is made from a pigment ground in varnish of the type mentioned above. The ingredients and the proportions of them are altered according to the effect desired, and according to the position of the coat, whether inside or outside and whether a priming coat, one of the other undercoats, or the finishing coat. For instance, pigment is ground, not in oil proper, but in a suitable oil varnish, where high gloss and smooth surface are required, and such mixtures are known as *varnish-paints* or *enamels* (§ 30), of which a large number are on the market and are popular as the finishing coat, especially for interior decoration.

The interior walls of offices and dwelling houses, though very often papered, are frequently painted, and still more frequently distempered (§ 83). *Distemper* is a water paint, i.e. a water solution of glue or a similar substance in which pigment has been ground and possibly other materials introduced for specific purposes; e.g. to make the surface less soluble to allow of a second coat being applied without washing up the first, and to

allow of light sponging to remove dirty marks, and so on. For interior walls a flat or matt effect is desired, and distemper yields this well. If oil paint is used for walls it can be so compounded as to give a similar appearance. This is more lasting and hygienic allowing, as it does, of frequent washing without detriment, but it is much more costly than distemper both in itself and in application. With oil paint several coats are necessary, and these must be applied laboriously with a small brush, whereas distemper will often give a good effect in one coat, seldom more than two coats being necessary, and a very large brush and unskilled labour may be used.

For the *waterproofing* of interior walls to prevent dampness, a preparation of bitumen may be applied (§ 71), or a waterproof varnish such as a solution of manilla resin, etc., in an alcoholic solvent (§ 77). Such coatings should be applied at a period when the wall in question has become temporarily dry. A coating for the same purpose which could be applied to a wet wall consists of an emulsion of a drying oil or varnish in a glue solution. For use on the exterior of walls, preparations containing such materials as linseed oil, mineral oils, and water-repelling waxes are effective.

**2. Floors.** For the floors of buildings special paints are sometimes used, which dry



very hard and tough. These contain linseed oil or other drying oil, a considerable proportion of resin, and the pigment. The bare wooden floor showing outside the carpet in private houses is usually coated with a shellac varnish (§ 74), or a short-oil varnish (§ 66), which will stand much hard usage before wearing away. Alternatively, the boards may be coated periodically with a mixture of beeswax, linseed oil and a volatile thinner (turpentine) by rubbing-in.

Concrete floors which may dust and disintegrate when subjected to much abrasion can be protected from this by special paints which also improve the appearance of the surface, making it not unlike linoleum. Linoleum itself is oxidized linseed oil containing pigment, dried to a firm film in layer upon layer on a canvas base; resins, powdered cork, etc., are often incorporated.

**3. Factories.** In factories the whole question is usually one of protection and hygiene. Metal work in the buildings and structures is protected with oil paint (§ 26) or bituminous coatings (§ 71), but the inside walls are covered with a wash of lime (calcium hydrate) in water, applied roughly with a large white-wash brush or a spraying machine. This lime-wash, to which common salt is sometimes added, serves the double purpose of cleansing the walls and whitening the surface thus

lightening the interiors. The amount of light available in an interior is affected by the light-reflecting power of the walls to a far greater extent than is usually appreciated.\* The lime in the course of a few days is principally converted to carbonate of lime which in this dry condition has great opacity and very high light-reflecting power.

**4. Protection of Iron and Steel.** One of the greatest problems before the engineer is to protect steel and iron structures from rust and consequent early destruction. The only method at present known is to coat the surface with a protective paint. For this purpose there are two types found effective, linseed oil paints (§ 26), similar to those used on the wood and stonework of dwellings, and black varnishes consisting of a solution of mineral bitumen, coal tar, pitch or similar material (§ 71). The latter admit of less skilful application and are much cheaper, but the former, if properly applied, protect the metal more certainly and effectively, besides allowing any coloured finish to be obtained. (See also §§ 55, 57.)

**5. Furniture, Small Articles, etc.** Small objects are coated to make them attractive,

\* See also *Elements of Illuminating Engineering*, by A. P. Trotter, uniform with this volume. (Pitman, 2s. 6d. net.)

this being done with a great variety of materials of which perhaps shellac is the most important. Many wooden articles are French polished (§ 76), or coated with a spirit varnish to show up the grain, to enrich the effect, and to give a gloss to the surface. This treatment is that usually accorded to furniture. Small metal objects are usually coated with a hard drying pigmented enamel of oil and resin, or shellac basis which is baked on : or they are lacquered with a solution of shellac (§ 74), celluloid (§ 80), or oil and resin, after being polished, etched or bronzed, the coating being usually baked (stoved). Thus bicycles and similar goods are usually dipped into an enamel composed largely of linseed oil varnish and are then stoved to render the enamel non-tacky and hard.

Motor-cars, especially when the body is of metal, are often stoved after the application of a similar enamel. When the body is of wood and sometimes when it is of metal, and also in the case of horse-drawn vehicles, the painting is usually done by hand, a large number of coats being put on. Each coat is well rubbed down, and to facilitate this the undercoats are usually paints containing linseed oil, much resin, and also pigment (coach-builders' flatting paints, § 69). The last two or three coats consist of flatting varnishes covered by a first-class long-oil copal varnish (§ 20). Thus the very finest finish is obtained.

**6. Submerged Surfaces.** For the coating of surfaces of all kinds which are to be submerged under water, special compositions of a bituminous nature (§ 71) are much used, and are effective if several thick coats are applied, each being allowed to get thoroughly dry before putting on the next. These compositions are useful under salt water as well as under fresh. Salt water is far more destructive to iron and other metal work than is fresh water, owing to the fact that it sets up electrolytic action on the surface of the metals. This effect is of very serious importance in the case of ships, the steel hulls of which are relatively thin and are held together by rivets, the presence of which increases the likelihood of electrolytic action. The hulls of ships are painted with special compositions to protect the metal from the influence of sea-water, and a final coating is applied which contains poison to prevent the attachment of barnacles and seaweed to the ship's sides and bottom, which would otherwise be overgrown in the course of a few months, so that the ship's speed would be reduced considerably or the coal consumption much increased. Owing to the severity of the conditions vessels should be recoated every six months, and satisfactory results can only be obtained by the use of high-class materials and expensive poisons, scientifically manufactured into anti-corrosive and anti-fouling compositions.

## CHAPTER II

### LINSEED OIL AND DRYING-OIL VARNISHES

**7. Linseed Oil: Raw and Refined.** Linseed oil is a yellow-brown or greenish oil of rather low viscosity and characteristic smell, which is obtained from the seed of the flax plant. It consists of the glycerides of several unsaturated fatty acids, the mixed acids being termed "linoleic" acid.

Its use in the paint and varnish industry is due to its property of setting to a tough material, called "linoxyn," when a thin film of the oil is exposed to the air.

The analytical constants of raw linseed oil are: specific gravity, 0.930 to 0.935. Refractive index (25° C.), 1.479 to 1.484. Iodine value, 170 to 195. Saponification value, 190 to 195. The free fatty acid is very low in good oil, but may increase in old badly pressed oil, by the action of fat-splitting enzymes; it should not exceed 3 per cent (Acid value, 6).

These data apply only to ordinary raw linseed oil. Owing to the long time that raw oil takes to dry, and owing to its low viscosity, it is necessary to modify its nature to some extent before using it in paints and varnishes. The modifications are usually brought about by heating, blowing with air and adding small

quantities of certain compounds, which act as catalysts in increasing the rate of oxygen absorption and hence solidification of the film (§ 11).

Fresh raw oil contains a good deal of suspended and dissolved matter which is thrown out as jelly-like particles when the oil is heated. This action is known as "breaking." The material thrown out consists of albuminous matter, phosphates, etc., from the seed cells.

Oil may be refined in several ways. It may be kept for a long period, six to twelve months, while the injurious materials separate out and settle down, the clear oil from the upper layers being known as "tanked" oil. The settlement is called "foots," and is used for inferior purposes, such as making putty. Such oil is not called "refined oil" in the trade, the name "refined" being retained for pale oils which have been treated to remove their colouring matter, without the addition of "driers" (§ 8). One method is to agitate the oil with about 1 per cent of strong sulphuric acid, which coagulates and chars colouring matter and other impurities. On washing to remove the last traces of acid, a fairly light coloured oil is obtained with other properties not different from those of the raw oil. This is the usual method of refining, and is called acid-refining.

Linseed oil may be bleached by strong sunlight or "ultra violet" light, but this

method does not seem to be used much, if at all, at the present time.

If the oil is heated to about 500° F. for a time and allowed to cool it becomes much paler but also somewhat more viscous, though still quite thin. Such a process is used for some purposes, and is called heat-refining. In conjunction with a filtering operation, to remove the albuminous substances, etc., which break away from fresh oils so heated, the process of refining is completed to yield an oil against which nothing can be urged on the score of chemical contamination as may be in the case of acid-refined oil.

Many refiners have what they believe to be secret processes and are able to produce oils of remarkably little colour at a quite small charge above the cost of raw linseed oil.

**8. Boiled Oil.** Linseed oil to which a drier has been added during a heating process is known as "boiled" oil. Originally such oils were made by heating the raw oil up to as much as 500° F. and then adding salts or oxides of lead and manganese in quite small quantity (§ 11). It has been found, however, that a much lower temperature yields much paler oils and steam heating is now mostly used. At this lower temperature the viscosity of the oil does not increase and, in order to produce this desired change, air is blown through the oil.

When oils are very dark and quick-drying, i.e. containing much lead, etc., in solution they are termed "double boiled."

When oils are specially treated to give a very light-coloured boiled oil, lighter than raw linseed oil, they are termed "pale-boiled" oils. Such oils should not have much manganese incorporated, and are usually dried with a small quantity of a cobalt compound.

**9. Stand Oil.** When linseed oil is heated it becomes slowly more and more viscous (as measured at low temperature). This change is believed to be a simple polymerization of the molecules since the saponification value, and acid value are but little altered even when a great change has taken place in physical properties. The drying capabilities are unaltered, and there does not appear to be any satisfactory evidence that the resulting oxidized film is other than the same linoxyn of raw oil. Such thickened oils are called "stand" oils. •

This polymerizing action takes place the more rapidly the higher the temperature, the curve being similar to that of tung oil in character (Fig. 3, § 25). A temperature of 300° C. produces an oil as thick as golden syrup (and very like it in appearance) in about six hours. If the temperature is taken too high, secondary changes take place with the setting free of fatty acids, the giving off of excessive acrolein vapours (decomposition of glycerine) and



darkening of the oil. The same undesirable effects may be produced by careless manipulation even at lower temperatures owing to local overheating.

If linseed oil is heated in iron vessels the free fatty acid, small though it may be in quantity, nevertheless dissolves a little of the iron and the iron linoleate darkens the oil; so that where the palest heat-treated oils are required copper or aluminium vessels must be used.

**10. Laboratory Work.** In connection with this it is well to reflect that the greater the bulk of oil treated at one time the less the proportionate area of metal in contact with oil, and in the same way the less the proportionate area of surface exposed to air and to the fire's heat.

This remark bears very definitely on the question of reproducing in the works the results obtained in the laboratory. Table I shows clearly the difference between a laboratory pot and a large works pot as regards the proportions mentioned. In order to have, in a laboratory experiment in a 1-litre pot, the same conditions as exist in a large works pot, as regards metal surface and air surface, the 1-litre vessel should have a metallic surface of only 50 sq. cm. and a neck of only 10 sq. cm., instead of areas ten times as great. The laboratory pot can, and should be, constructed to fulfil these conditions.

TABLE I  
COMPARISON BETWEEN LABORATORY POT AND  
LARGE WORKS POT

	Laboratory Pot. (1 litre.)	Large Works Pot. (approx. 1 ton.)
Volume of oil, cu. cm.	1000	1,000,000
Area of oil surface, sq. cm.	100	10,000
Surface of metal in contact with oil, sq. cm.	500	50,000
Ratio of air surface to oil volume . . .	0.1	0.01
Ratio of metal surface to oil volume . . .	0.5	0.05

Similar discrepancies in conditions will be found on all sides, the more obvious being rate of heating and cooling. These and other factors are clearly the cause of the frequent failure to reproduce laboratory operations on a works scale, and thus these discrepancies should be recognized by the chemist and eliminated as far as possible by suitable expedients whenever the laboratory experiments are intended as forerunners of works operations.

**11. Driers.** Practically the only catalysts used to hasten the oxidation of drying oils are compounds of lead, manganese, and cobalt. The compounds which are active as driers are those which dissolve in the oil and become

part of it, such as the rosinate, linoleate, and oleate (§ 68). The method by which these compounds are made, and introduced into the oil, or formed in the oil *in situ*, is immaterial

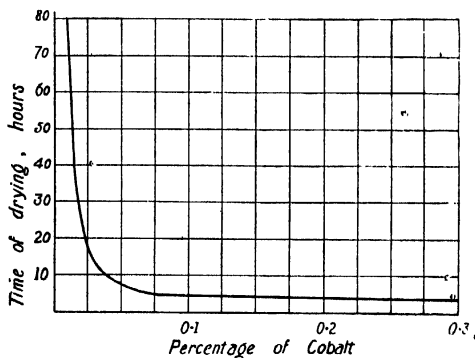


FIG. 1.—EFFECT OF A CATALYST (COBALT) ON THE DRYING OF LINSEED OIL, AT 60° F.

*Note.*—The time of drying is also affected by humidity, ventilation, and light.

as regards drying power; the quantities and proportions of the metals in solution being the governing factors.

Thus, cobalt oleate or linoleate may be made by precipitating sodium oleate or linoleate with a soluble cobalt salt, such as the chloride, in aqueous solution; cobalt rosinate may be made by dissolving cobalt hydrate or acetate in melted rosin at a high temperature; yet the time of drying of two oils to which

each of these driers have been added will be the same, providing that the percentage of metal actually in solution in the oils is the same in both cases.

In this matter of driers, dealing as we are with catalysts, we should expect them to follow the laws of catalytic action, as unravelled in other branches of chemistry. This they appear to do. The reaction is a time reaction, the rate of which increases with increase of temperature and with increase of concentration of the catalyst (Fig. 1); but the author knows of no quantitative investigations yet made to determine the exact physico-chemical facts. The subject is awkward owing to the difficulty of measuring the oxygen absorption, and still more owing to the imposition of other factors affecting the rate of oxidation, namely, the flow of air over the surface (a quick flow increases the rate of drying), the degree of moisture in the air, the absence or presence of light, and the thickness of the layer which can, of course, only react at its surface.

We find in this subject what appear to be examples of activation of catalysts (promotor actions), inasmuch as several of the metals which can cause the drying of linseed oil require the presence of much smaller quantities of other metals before they will function. In addition there is evidence that the metals only act as makers of the actual

catalytic agent, an organic peroxide body. Lead alone acts only feebly as a drier, but very small quantities of cobalt or manganese and certain other metals will greatly accelerate the reaction. Speaking always of molecularly equivalent quantities, manganese is almost as bad a drier when alone as is lead, but cobalt is a powerful drier when quite alone. Cerium can be activated by manganese in the same way as lead is activated, and it is similar in drying powers. Zinc, though often referred to as a "drier" does not exert any drying action in the same sense as do lead, manganese, and cobalt. Iron acts as a drier when in conjunction with manganese, though rather weakly. Most other metals have no drying powers.

Thus it is that we find the most commonly used drier to be not lead alone or manganese alone, but a lead-manganese combination; while cobalt is generally used alone.

The commonest drier is lead-manganese rosinate, the lead being much in excess of the manganese. This is made by adding litharge ( $PbO$ ) and pyrolusite ( $MnO_2$ ) to molten rosin and prolonging the heating till solution of the oxides is effected in the acid rosin, producing the rosinate which may then be dissolved in white spirit (§ 15) for convenience in adding to paint. This liquid is called terebine (§ 68).

The quantities of metal required to be in solution in oil to make it dry in a reasonable

time (8 hours at 15° C.) may be taken as, in the neighbourhood of, lead 0.5 per cent, together with manganese 0.05 per cent; or cobalt alone 0.05 per cent.

**12. Copal Varnish.** *Definition.* The name "copal varnish" has long been known to cover that class of coating which dries partially by the evaporation of a volatile ingredient (turpentine, etc.) and partly by solidification of the remaining homogeneous film composed of an intimate blend of copal resin and linseed oil (§ 7).

Unfortunately the name has often been misapplied to other and inferior products in which there is no copal resin and in many of which rosin (§ 79) or rosinated preponderate. Such varnishes, while suitable for some purposes, which do not involve exposure to weather or abrasion, are usually rapidly disintegrated by the action of sun, rain and wind. Latterly, however, means have been discovered whereby varnishes, not containing any copal resin, may be manufactured which bear comparison with genuine copal varnishes in colour, rate of drying, lack of tackiness in the film, toughness of the film, resistance to rubbing, weather, moisture, etc., and in general appearance and durability; and which even surpass the genuine copal varnish in some of these qualities. This type of varnish is made from that hitherto undesirable substance rosin, with which Chinese

wood oil (tung oil) has been compounded (§ 24).

*Ingredients.* The ingredients of copal varnishes are linseed oil (§ 7), a volatile "thinner," and the copal resin itself. The volatile thinner may be turpentine or white spirit.

**13. Turpentine.** Turpentine is the product of the distillation of the resinous exudation ("oleo-resin") of a considerable variety of conifers (pines). The distillate is turpentine and the residue is the rosin or colophony of commerce (§ 79).

American turpentine has a specific gravity 0.860 to 0.875, is water white, and has a not unpleasant characteristic odour. It distils almost completely between the temperatures 150° to 170° C. The refractive index is 1.46 to 1.48. It is usually dextro-rotatory, while French turpentine is usually laevo-rotatory.

**14. White Spirit.** White spirit used in the paint trade is a product of the distillation of petroleum and is expected to conform, as closely as is consistent with its comparatively low price, with the volatility of turpentine; for turpentine has been found by long experience to have a rate of evaporation convenient for the application of coatings containing it. White spirit, owing to its nature and consisting as it does of a mixture of homologues of graduated boiling points, cannot have so

regular a rate of evaporation as turpentine. The usual figures expected of white spirit are as follows—

Distillation points 145°C. to 210°C. with no oily residue.

Flash point above 73°C. (to avoid coming under certain provisions of the Petroleum Act).

White spirits are also made which do not conform to this general specification, but in which special attributes are required. Amongst these are low volatility and high flash point; low volatility for use in flat-drying paints where the rate of evaporation shown by turpentine may sometimes be too great; high flash point for those paints in which a large proportion of the white spirit is used and which must conform to shipping companies' rules regarding inflammability.

**15. Copals.** The resins used in making oil varnishes are all called "copal" by courtesy, whatever may be their source, with some exceptions such as rosin (§ 79) and amber. This classing together of the oil varnish resins is justified as they do not differ from one another very much when made up into varnish, so little in fact that it requires expert knowledge to warrant an opinion even after careful tests have been made.

The original true copal is that from the East Coast of Africa called Zanzibar copal



or animi, and this is still the best of the copals, yielding the finest varnishes. Copals may be divided into two distinct classes: (1) those that are of recent origin, (2) those of prehistoric origin and called "fossil." The latter class is by far the harder and better for the purpose of making resistant varnishes. The copals are usually named after the country or port of shipment, and so it is easy to see how copal resins bearing the same name may yet be of different origin and nature. Thus from Manilla we have a hard resin used for oil-varnish making and a soft resin (§ 77) used for making spirit-varnishes, and there are grades of intermediate degrees of hardness.

Among the commercial copals there may be mentioned—

Zanzibar . . .	East Africa
Sierra Leone . . .	} West Africa
Angola . . .	
Congo . . .	
Manilla . . .	East Indies
Kauri . . .	New Zealand

The areas from which these come mostly yield resins of both types, fossil and recent, the fossil being much harder, of higher melting point, and the more valuable type.

**16. Varnish Plant.** The varnish factory is so arranged that a series of pots can be heated over furnaces and quickly removed therefrom

at will. It is usual to have the furnaces below the floor so that the pot may rest in a hole over the furnace in such a manner that only a small portion (4 in. to 8 in.) of it is below the floor level, and consequently being fiercely

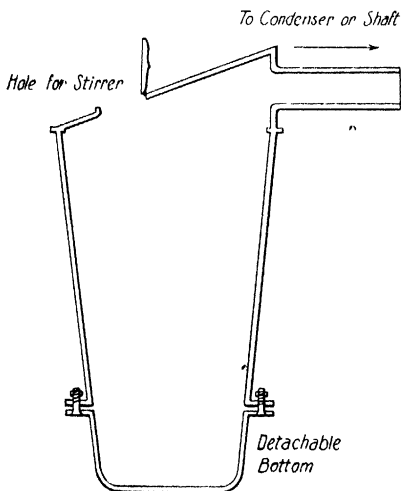


FIG. 2. - VARNISH POT.

heated. The pots used vary considerably in size in different works, but are always more or less of the type shown in Fig. 2. There is a hood leading to a shaft which carries away the fumes generated. The hood may be well

above the top of the pots or closely fitting, but in any case it allows of the free use of a hand stirrer. The pots are usually conical in shape, the upper portion being the wider, or are cylindrical, and have a flange at a suitable distance from the bottom which serves to support them when "sitting" over the fire. The bottom can be made detachable at the flange, to enable a new one to be fitted without returning the pot to the makers. From out the sides there may protrude studs or lugs by which the pots may be lifted with care and carried away on a hand carriage, or they may be permanently fitted to a truck. The particular design will depend on the quantity of gum to be melted at a time. This varies from a few pounds up to half a hundredweight or more; the tendency being to use larger pots which can now be done owing to the use of modern machinery, electric power, etc.

The pots are made of iron, copper, aluminium or of a suitable alloy. The use of iron tends to darken the varnish as the iron compounds, formed to a small extent, are very deep red-brown in colour. The traces of copper dissolved from copper pots are green, but are not in sufficient quantity to influence materially the colour of the resins. Aluminium has the advantage that its compounds are entirely free from colour; also, the metal is a good conductor of heat and this, in a thick pot, helps to prevent local overheating and

consequent charring. The disadvantages of aluminium are its low melting point and its softness.

The furnaces are fed from either inside or outside the building, and are often gas-heated. Provision is made for accidental ignition, and should a pot catch fire it is immediately wheeled outside and a hood placed over it to smother the flames.

The pots are always very big in proportion to the quantity of resin melted in them because there is much frothing during the process. The pot must always be filled with gum above the level of the floor, otherwise the heat of the fire acting at the surface of the gum might fire it.

**•17. Melting Resin in Varnish-Making.** The melting of the resin is known as "gum running." The correct quantity of resin, in pieces not too large (up to the size of walnuts), is placed in a pot and put over a fire as described (the stirrer being worked about a little now and again). This stirring becomes easier as the resin melts and finally the resin can be stirred as easily as oil and will run off the stirrer as a limpid liquid. During the melting much fume is given off, which amounts to from 5 per cent to 30 per cent by weight of the resin, and may be condensed and used in certain types of paint (§ 64). The quantity depends on the particular resin under treatment, on the degree

to which it is desired destructively to distil the resin, and to some extent on the skill of the manipulator.

The proportion usually distilled away of the different resins before they become fit for amalgamation with oil is roughly as follows—

Zanzibar	.	.	15-20 $\frac{0}{10}$
Sierra Leone	.	.	10-15 $\frac{0}{10}$
Angola	.	.	20-25 $\frac{0}{10}$
Congo	.	.	25-30 $\frac{0}{10}$
Manilla	.	.	25-30 $\frac{0}{10}$
Kauri	.	.	15-20 $\frac{0}{10}$

This loss must be taken into consideration when calculating the proportion of oil desired in the finished product. The amount of loss will vary with each delivery of resin and the exact loss to be expected can only be gauged by a trial run under working conditions. Tests on a small scale in the laboratory may be misleading, since the loss will depend to a considerable extent on the time taken, temperature of walls of pot, rate at which fumes are carried away, final temperature, etc. (§ 10).

When the resin is melted to the correct degree, which is usually taken as being that condition when the liquid will run freely off the stirrer and contains no lumps of unmelted resin, the oil is introduced little by little (§ 19) in such proportions that the mass is not chilled sufficiently to cause a separation of the resin and added oil. To assist this, the oil is added hot, it having been got ready in

another pot. It will assist the varnish maker to make use of thermometers in the oil and in the resin mixture, and to keep a record of these temperatures as the process proceeds for future reference and to assist him in tracing the cause should any batch turn out different from expectation in any particular. The use of thermometers is especially necessary when dealing with Chinese wood oil (§ 25) or any mixture containing it.

### 18. Preparation of Oil in Varnish-making.

Only the best tanked or heat-refined oils (§ 7) should be used for varnish-making, any inferior batches of oil being kept for making boiled oil or for use in the rougher types of paints.

- It is necessary to specify tanked oil as it is essential to the production of good varnishes that the oil should not "break," i.e. throw albuminous and other materials out of solution when heated.

While the resin is being prepared, the oil in the quantity required for the run is heated up to a convenient temperature for its addition to the resin, say, 150° to 200° C., and that may be all; or the oil may be "bodied up" considerably, approaching stand oil (§ 9) in consistency, by heating for a considerable period, say three or four hours or more, at 300° C. The latter type of oil requires more care to be taken in adding it to the melted

resin as it is more likely to refuse to mix and spoil the batch by charring and solidification.

Sometimes Chinese wood oil is used in conjunction with linseed oil for oiling-up the resin, and when this is used extreme care has to be taken to avoid solidification, which will occur in this case even after the oil has been satisfactorily combined with the resin. It may happen with very little warning, the whole mass going solid and being then practically unusable for any purpose. This danger is increased by an increase in the proportion of the wood oil, and it is very difficult to avoid disaster when the proportion of wood oil exceeds 50 per cent of the oil.

**19. Oiling-up Resin.** If the oil is added in too great a quantity at a time, some of it will not immediately dissolve in the resin and a mixture of resin-oil and oil results, and the necessarily high temperature of the process being too high for the uncombined oil, polymerization and solidification may occur before complete amalgamation is effected. The whole batch is then spoiled. To avoid this risk, the oil is added in small quantities at a time so that the whole of the addition is immediately dissolved by the resin. That this has occurred each time can be seen by noting if the fused mass is still limpid and clear. If now a spot of the mixture be dropped on to a piece of glass it will be seen to be clear, but it will

become cloudy as it cools ; this cloudiness is due to the resin and oil separating again at the lower temperature. The mass in the pot is now maintained at the heat found most suitable by previous experience until a drop upon glass no longer becomes cloudy on getting cold. It is then time for a further addition of oil in the same way as before. The mass is heated and tested for amalgamation as after the first addition before a third addition is made, and so on until all the oil has been added and the last addition tested for complete combination, when a drop of the varnish should still remain perfectly clear.

It will be seen from the foregoing description of the oiling-up of a resin that the combination is not merely a physical mixing or solution but that a chemical reaction takes place between the resin and the oil which takes a definite time, decreasing with temperature, for its fulfilment as do most organic reactions (the so-called "time reactions").

A rough and ready method of oiling-up in small batches is to allow the resin to froth up in the pot after melting, add one-third of the oil which, cooling the mass, causes the froth to break and settle down, then continue the fierce heating till frothing again occurs, add one-third more oil to destroy the froth and repeat so that all the oil has been added. Finally, a test is made for the completion of the reaction as above.



**20. Thinning Varnish.** After the oiling-up process, the varnish is finished off by wheeling the pot away from the fire and out into the open where turpentine or white spirit or other volatile thinner is added as soon as the temperature has fallen low enough to make this proceeding possible (but see also § 21). The temperature of the varnish mass should be as low as practicable to avoid loss of volatile spirit by boiling or evaporation. In long-oil varnishes, that is those containing a high proportion of oil (from 70 per cent upwards), the thinning may be done at quite a low temperature as such a mixture of oil and resin can easily be stirred until it is quite cool, but with a short-oil varnish (§ 66), that is one in which there is only from 30 per cent to 50 per cent of oil, the volatile thinner has to be put in while the resinous mixture may even be above the boiling point of the volatile matter, and hence frothing and loss occurs during its addition.

**21. Set-Pot Process.** The varnish is often put through an additional process before thinning out, namely, heating in a large "set" pot at a high temperature, for some hours, up to six hours, in order to thicken the varnish mass (or the oil it contains) much in the same way as stand oil is made (§ 9).

A set pot is a large pot built in by brickwork and fitted with a hood to carry away the

fumes. It may be fitted with power stirrers and is usually made of steel or iron. This does not darken the oils so much as when used in the smaller pots because the ratio of iron surface attacked to volume of varnish is much lower (§ 10); also, the temperatures encountered are lower although the time of exposure to the surface is greater. Another purpose of the set pot treatment is to make one uniform whole of a number of separate varnish runs. The set pot contains many separate runs, and so the heating in it may vary from half-an-hour to three hours according to the purpose of the treatment.

**22. Adding Driers to Varnish.** Varnishes made as above would take too long to dry unless a "drier" (§ 11) were added at some time during the process. Driers may be incorporated in several ways—

(a) By treating the oil with litharge and manganese borate, oxalate or similar compounds, when heating it before adding it to the fused resin. This method is not to be recommended because only dark varnishes could thus be obtained, and no satisfactory argument can be suggested in its favour.

(b) By addition of litharge and a suitable manganese salt, or manganese dioxide to the hot mass after oiling-up is completed. This also will tend to darken the varnish, especially if the black oxide of manganese is used.

(c) By addition of rosinate or linoleate of lead and manganese, after the oiling-up process. This is the more usual method.

(d) By addition of liquid drier or terebine (§ 68) to the varnish during the thinning process with the volatile spirit. This method is to be recommended as interfering least with the colour of the varnish, and is the least likely to complicate the manufacture by causing skins to form and premature oxidation to occur as may happen when one of the other methods is adopted.

(e) By "churning" the completed and cooled varnish in a simple horizontal mixer with the requisite litharge, etc., in which case dried zinc sulphate or ferrous sulphate is generally added as well. Such churned varnishes are usually very pale and clear, but tend to be slow drying.

**23. Tanking Varnishes.** The last treatment to which varnishes are put is one of clarification, for which the best method is to allow them to remain in large tanks at a uniform temperature for a very long period, up to a year or more.

The traces of undissolved resin, inorganic matter, excess driers, and gelatinous flocs from the oil gradually settle down leaving the varnish clear and in such a condition that it can yield a perfect, full-gloss surface unmarred by any irregularities. A quicker method

which is used for cheaper grades of varnish and has come into more favour in recent years is to pass the varnish through a centrifuge or filter-press,\* either whilst it is still warm, or after standing some little time to cool and allow the impurities which would be thrown out on cooling to be removed.

**24. Wood Oil Varnishes.** As has been previously mentioned there have been made in recent years quite excellent varnishes, suitable for use in the place of "copal" varnishes but not containing any "copal." This result has been attained by the use of Chinese wood oil or tung oil (§ 25) in conjunction with common rosin (§ 79).

These varnishes are remarkable for the way in which their oxidized films appear to resist the absorption of water, for they do not become milky when exposed to rain or mist ("blooming") as do nearly all other types of varnish containing much oil. They may be made very elastic by including a large proportion of linseed oil in the recipe, and may even then be very tough. They grow progressively harder and tougher as time passes to a much greater extent than do the true copal varnishes, and by the shrinkage of the film they tend to yield large open cracks

\* For information on these machines and other filtration processes, see *Filtration*, by Roland Wollaston, uniform with this volume. (Pitman, 2s. 6d. net.)

after long exposure, whereas copal varnishes though cracking earlier show small cracks which do not open. They resist abrasion and scratching very well.

**25. Tung Oil.** Chinese wood oil or tung oil is a rather viscous, light-coloured oil of

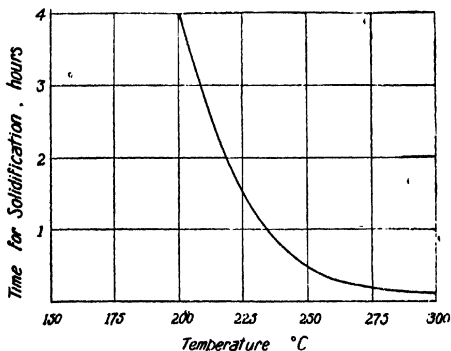


FIG. 3. —POLYMERIZATION CURVE FOR TUNG OIL.

*Note.*—At 160° C. the time for solidification is 25 hours.

characteristic unpleasant odour. It dries more rapidly than linseed oil when spread in a thin layer and exposed to air but, unlike linseed oil, its dry film is opaque, waxy and wrinkled. When suitably treated (dried), however, the film can be glossy, clear, hard and tough. Another characteristic property

s that of thickening and finally gelatinizing to a firm almost dry mass when heated above 250° C. for a few minutes. The rate of polymerization varies with temperature, see Fig. 3. The presence of fatty acids, rosin, or lime will delay this polymerizing action, which is used as a test of purity.

The physical characteristics of tung oil are—Sp. Gr., 0.940 to 0.943. Refractive index, 1.52. Iodine value, 165. Saponification value, 190 to 195.

## CHAPTER III

### DRYING-OIL PAINTS

**26. Typical Recipe.** For this discussion of paint it will be convenient to take a good all-round recipe, show how it is evolved, and explain the functions of the several ingredients. Such a recipe is—

	Per cent by Weight
Boiled Linseed Oil (§ 8) . . . . .	30
Zinc Oxide (§ 37) . . . . .	20
White Lead (§ 40) (Basic Carbonate) . . . . .	20
Barytes (§ 43) . . . . .	20
Coloured Pigment . . . . .	5
White Spirit (§ 14) . . . . .	4
Drier (§ 68) . . . . .	1

It has been the custom in the building and decorating trade to refer to stiff pastes of pigments in oil as “paint,” but in this work the word “paint” always refers to the coating material as prepared for use.

**27. Oil for Paints.** The oil is the basis of the mixture and gives it its cohesion after application and completion of the setting process with the formation of the solid film (“linoxyn”). It is also the principal agent in resisting the destructive agencies. Oil

alone, however, does not give adequate protection or good appearance because it is so thin that—

(1) It soaks in to many surfaces.

(2) It recedes from raised portions of an unsmooth surface, leaving these portions practically unprotected, and runs down in drops, leaving some areas very thinly covered.

(3) It dries soft and somewhat tacky. These defects are corrected in the admixture called "paint."

The soaking-in is allowed for by giving two or more coats, but it should be realized that this property is desirable in the first coat to enable this coat to get a firm hold on the surface—the oil flowing into the material and drying therein in union with that oil which remains in the solid powder ingredients of the paint.

The tendency to drain away from raised portions of the surface is overcome by the presence of the solids which, giving a slight pastiness, reduce the capacity for flowing, hold the oil on the raised portions of the surface by capillarity, and in the same way prevent the oil from flowing down in drops (§ 28). Of course, there are infinite gradations between pure oil which can only remain in a very thin layer on a vertical surface (the thickness of the layer depending principally on the viscosity of the oil) and a thick pasty paint which will stay on a surface as thickly as one



cares to place it there. A desirable consistency for a normal type of paint is that which will not allow the paint to run down a vertical surface, unless applied more thickly than will yield a film which will set right through (§ 31) in the course of a reasonable period, say, twenty-four hours. At the same time the actual medium must be of low enough viscosity to enable the brush to work it freely over the surface.

The third defect of pure oil—that of drying soft and tacky—is rendered less evident by the pigment which now enters into the composition of the surface of the paint, lessening the effective area of “dried” oil which is the sticky portion and also probably functioning by partially absorbing the still liquid portions of the oxidized oil film which are the cause of this stickiness.

Moreover, another factor is introduced in consideration of paint, inasmuch as some of the solid powders added enter into an actual chemical union with the medium, causing in some cases an increase in the consistency and, what is more important, causing a change in the chemical and physical nature of the final oxidized product.

**28. Mixed Pigments.** This brings us to the chief reason for the introduction of two opaque white ingredients in our specimen recipe (§ 26). Linseed oil when ground with

basic carbonate of lead gradually combines with it to some extent and the film from such a paint after being dry a long time, has quite different properties from those found when zinc oxide is used instead of lead carbonate. The lead paint film is softer, and the zinc harder but more brittle, while the lead wears away under atmospheric influences more easily than the zinc. The use of a mixture of the two pigments modifies the defects of each to give a result which is better than that obtained when either is used separately. It seems probable that, in the change from oil to linoxyn, active constituents of the pigments enter into combination with the linoxyn, considerably modifying the properties of the final product. Thus when zinc and lead active compounds (zinc oxide and basic lead carbonate or basic lead sulphate, § 41) are both present, the product is partly the zinc compound with its own capabilities and partly the lead compound with its own special characteristics.

Barytes, although practically transparent in oil, is usually introduced into the specification of a paint as it is a cheap article, and so lowers the cost "per.cwt." (§ 62), but it must not be thought that this is its only recommendation. It functions satisfactorily as a solid powder, producing the specific qualities of paint as distinct from those of varnish, as already described. The particles of barytes will lie closely together, thus yielding a denser

mixture than can be obtained with other fillers, and this property is believed to be advantageous in a paint, increasing its durability (analogously with cement); and also permits a thicker layer to be obtained in one coat (§ 31).

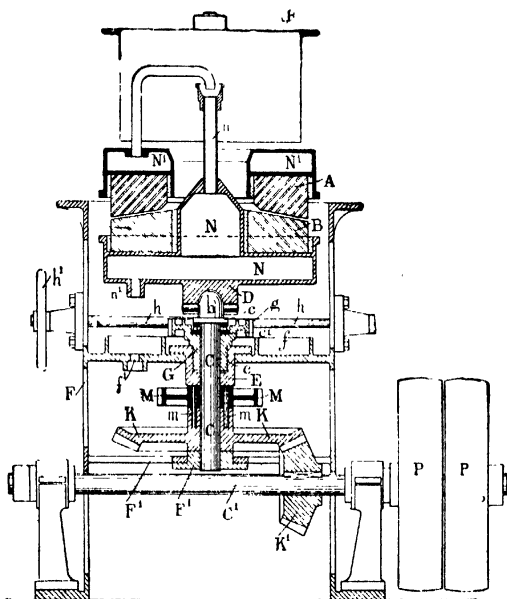
The coloured pigment is not introduced solely on the score of colour, since tinted paints have been proved more durable than white. If white were required, the coloured pigment would be replaced by more of the white pigments. The turpentine or white spirit is put in to assist in application—it reduces the viscosity of the medium, thus allowing freer working under the brush. It evaporates quickly, and enables the paint to set (become more pasty) before separation into layers (according to specific gravity of pigments, etc.) or exposure of raised points of the coated surface can take place to any great extent.

**29. Percentage and Kind of Oil.** To refer again to the most important portion of the specification, namely, the oil, 30 per cent of oil gives a good paint with good gloss and maximum protective power, but a considerably lower percentage could be used. If the percentage of oil be increased, the paint tends in proportion to become too fluid and to show the defects of the oil alone (§ 27). The oil here specified is boiled linseed oil, but

if the paint is to be used as a first coat on a porous or perished surface it is advantageous partially or wholly to substitute this boiled oil with raw linseed oil (to which the necessary extra drier has been added) because of its greater penetrating power, due in part to lower viscosity. Recent American official specifications frequently indicate raw or refined linseed oil (adequately driered) instead of boiled oil, which, in England especially, is more usual. If the surface to be painted is very absorbent the proportion of oil should be increased to allow for this.

**30. Enamels.** If a very high gloss is required for the finishing coat, for the sake of its appearance, or to have a surface which would be as little as possible likely to harbour dust, bacteria, etc. ; then the introduction of copal varnish and the reduction of the proportion of pigment will achieve this, for reasons which are obvious — this approaches the nature of an “ enamel,” which is nothing but a very finely ground paint (§ 34), usually of very high gloss.

White enamels are largely used for interior woodwork, and will last for very long periods. They will stand frequent washing without detriment to the surface and after many years their appearance may be better than when fresh, if carefully treated. Enamels are not used very much for exteriors, but here they



- |     |                                     |     |  |
|-----|-------------------------------------|-----|--|
| A   | = Upper stone.                      | ff' | = Open water tray and water outlet.          |
| B   | = Lower stone.                      | G   | = Bearing adjustable for rise and fall.      |
| b   | = Spindle head.                     | hh' | = Adjusting shaft and wheel.                 |
| CC' | = Centre spindle and driving shaft. | KK' | = Reel gear.                                 |
| cc' | = Collar of spindle, and ball race. | M   | = Cog wheel driving stirrer in mixer at top. |
| D   | = Water jacket.                     | NN' | = Water spaces.                              |
| E   | = Fixed casting.                    | n   | = Water pipe.                                |
| e   | = Threaded surface.                 | n'  | = Water outlet to tray f.                    |
| F'  | = Bearing.                          | PP  | = Fast and loose pulleys.                    |
| FF' | = Frame.                            |     |  |

FIG. 4. --WATER-COOLED FLAT-STONE MILL FOR ENAMEL AND OTHER VERY FINE GRINDING.

would be found to give excellent service as finishing coats.

These remarks apply only to enamels which are made properly and from the best materials. The suitable materials are long-oil copal varnishes (§ 20) and "stand" oil (§ 9) as the binding media, and, in the case of whites and tints, zinc oxide as pure as possible as the white pigment. In order that the correct enamel-like surface may be obtained, enamels are made rather viscous and considerable skill is required to get a good even layer upon the surface, without allowing brush-marks or runs to show.\*

The details of the specifications and manufacture of the many proprietary white enamels are guarded secrets, but it may be taken that—

(1) Zinc oxide of the best possible colour and purity is used.

(2) The medium does not "feed" (i.e. combine chemically) with zinc, or does so only to a small extent.

(3) The medium is thick and an excess is used.

(4) The drier is a pale one, usually with cobalt as the active principle (*cp.* pale boiled oil, §8).

(5) The grinding of the zinc oxide is done very finely indeed (§34).

**31. Thickness of Oil-Paint Film.** The thickness of an ordinary driered linseed oil film which will dry solid right through in a

Practical hints on painting, enamelling, etc., are given in *House Decorations and Repairs*, by Wm. Prebble, uniform with this volume. (Pitman, 2s. 6d. net.)

reasonable time is about 0.03 mm. . If oil in a layer appreciably thicker than this is exposed to air, a skin of approximately this thickness forms, leaving a still fluid layer between the solid film and the underlying surface, which remains fluid for a very long time. The amount of linseed oil dried by unit surface exposed to air is a more or less fixed quantity. Now, if the oil is mixed with pigment in the form of paint the amount of oil dried (oxidized) per unit surface remains about the same, but owing to the presence of the solid pigment particles, this represents a thicker layer, consequently the greater the proportion of pigment present *by volume*, the thicker the layer of paint which will dry to a solid film right through.

As the thickness of a simple oil film formed is about 0.03 mm., and that of a paint, say, 0.05 mm., it will be desirable to make the paint of such a consistency that it will ordinarily spread in a layer thinner than this, to allow for the inevitable unevenness of a surface and of a man's work, causing thicker layers in some parts than in others. This covering capacity of the paint will represent about 50 sq. ft. per lb. or about 600 sq. yd. per cwt. for a paint of specific gravity 2.0, weighing 20 lb. per gallon.

The above remarks are intended only as rough guides to an understanding of the subject, for many other factors enter into

the matter. For instance, the presence of certain substances will increase the thickness of the layer of oil that will dry through on exposure to air. Zinc oxide has this effect, as is seen notably in enamels (§ 30), possibly by combining ("feeding") with acid substances formed during the oxidation of the oil before the formation of the firm linolein itself. Chinese wood oil (§ 25) causes, under certain conditions, the formation of quite a thick solid skin, indeed some mixtures made up into varnish will show a gelatinous skin up to an inch in thickness in the package.

**32. Specifications for Oil Paints.** In the compounding of paints it is extremely important as well as a useful guide to remember that pigments vary greatly in the amount of oil required to make a stiff paste with them, and that the volume of oil required to make a practical paint of similar working ease will in each case be the same proportion of the paste, *by volume*, say, about one-half. Thus a pigment which requires more oil than another to make a stiff paste requires even more, in proportion, to make a workable paint. This is the root of the generally believed inferiority of zinc oxide compared with white lead as an obliterating agent when made up into paint, in spite of the much greater opacity of zinc oxide pigment, weight for weight (§ 33).

As a useful guide, the following may be



taken as satisfactory specifications for paint, and are mostly based upon British official requirements. In each case the drier is specified to be added in such quantity that the paint dries in from 10 to 15 hours at 15° C. The paint must dry to a semi-glossy film.

TABLE II  
TYPICAL SPECIFICATIONS FOR OIL PAINTS

PIGMENT.	Percentages, by weight.		
	Pig- ment.	Oil.	White Spirit.
Basic Carbonate White Lead (§ 40)	84	12	4
Zinc Oxide (§ 37)	72	23	5
Lithopone (§ 39)	76	20	4
Black Oxide of Iron (§ 52)	70	26	4
Red Oxide of Iron (§ 52)	64	31	5
Yellow Oxide of Iron (Qchre) (§ 54)	58	36	6
Mid Yellow Chrome	} (§ 56)	29	6
Orange Chrome			
Monochrome			
Light Brunswick Greens	} (§ 60)	19	3
Dark Brunswick Greens			
(Containing 90% barytes)			
Umber, raw or burnt (§ 53)	50	45	5
Lithol Red Lake (§ 62) on blanc fixe (§ 44)	80	17	3

**33. Importance of Volumetric Composition.**  
Since the ingredients are all bought by weight and most paints are sold by weight, this has

led to an unfortunate mental attitude, in regard to the qualities of the various ingredients, in which a weight basis is taken for comparison whereas a volume basis would be the more correct one. Thus, in comparing one pigment with another with regard to its behaviour in paint the proportion of pigment to oil *by volume* should be considered and not the proportion *by weight*, as is so often quoted; to do this, one must determine the specific gravity of the particles, and the whole matter should be thoroughly examined (see Table III).

TABLE III  
PHYSICAL CHARACTERISTICS OF TYPICAL PIGMENTS

PIGMENT SUBSTANCE.	Absolute Specific Gravity of Particles.	Absolute Specific Volume of Particles.*	Volume of unit weight dry Powder.	Oil required to make 100 pts.(by w'ght) into Paste.
	Water = 1.0	Cu. cm. per gm.†	Cu. cm. per gm.	Parts, by weight.
Barytes . . .	4.3	0.23	0.42	9
China Clay . .	2.4	0.42	1.2	50
Oxide of Iron (Turkey Red)	5.0	0.20	0.77	25
White Lead . .	6.5	0.15	0.42	8
Zinc Oxide . .	5.3	0.19	1.1	16
Ochre . . .	3.5	0.29	0.96	30
Red Lead . . .	9.0	0.11	0.30	9

Assuming no interstices.

The ability to spread under the brush with a given quantity of oil appears to decrease with increasing oil absorption (i.e. the quantity of oil required to make the pigment into a

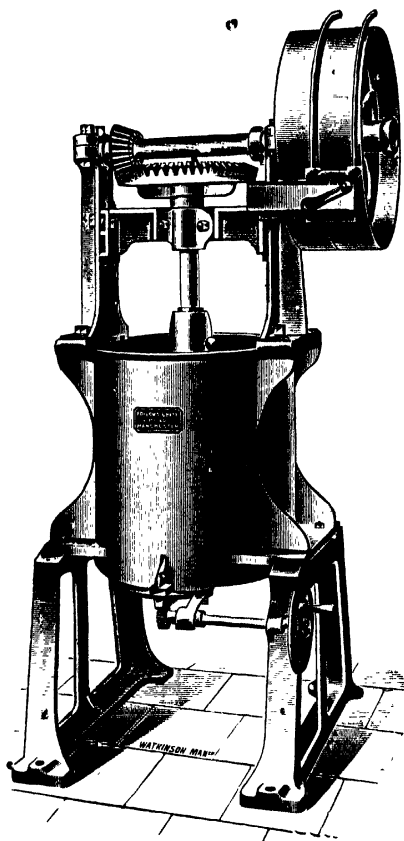


FIG. 5.—VERTICAL PUG MILL FOR MIXING  
STIFF PASTES.

stiff paste), while the ability to level or flow out appears to bear a relation to the volume occupied by unit weight of dry powder pigment,

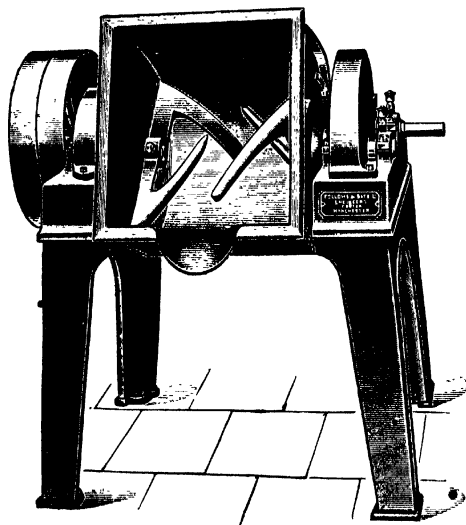


FIG. 6.—HORIZONTAL PUG MILL FOR MIXING STIFF PASTES.

Shown tipped for emptying.

the denser powders making more easily levelling paints. The paint chemist should be familiar with these physical properties of the various pigments he uses ; their bearing on the costing question, both in regard to cost per cwt.

and cost per gallon, especially under fluctuating market conditions ; and their bearing on the

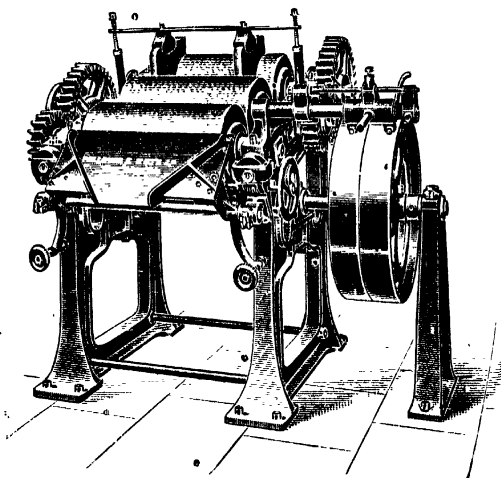


FIG. 7. —TRIPLE-ROLLER MILL WITH GRANITE ROLLERS,  
FOR GRINDING STIFF PASTES.

(See also Fig. 8.)

working qualities, flow, opacity, gloss, and durability of the paints made from them.

**34. Manufacture of Oil Paints.** The process of paint-making is simple ; the oil medium is incorporated with the pigments by grinding. First a thick paste is made by mixing oil and

pigment in a pug mill (Figs. 5 and 6, pp. 46, 47) and passing the mixture between granite rollers revolving at different speeds, as shown in Figs. 7 and 8, pp. 48, 49.

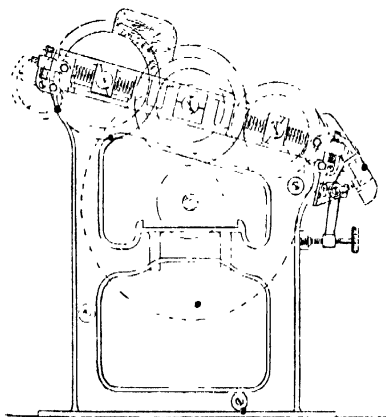


FIG. 8.—END ELEVATION OF TRIPLE-ROLLER MILL  
AS IN FIG. 7.

Showing springs holding rollers, and one method of gearing to obtain different speeds of rollers. The gearing illustrated gives roller speeds in the ratio 1:2:4.

The rollers may be 2 ft. or 3 ft. in length, and the centre one may have also a lateral motion.

After grinding in the rollers the paste is thinned out in a horizontal or vertical cylinder fitted with stirrers (Figs. 9 and 10, p. 50); or,

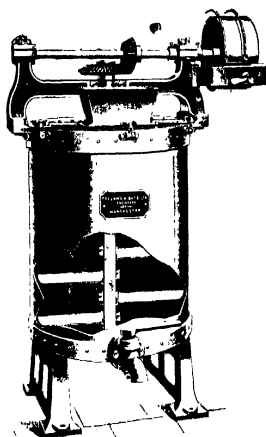


FIG. 9.—VERTICAL MIXER FOR FINAL THINNING  
AND AMALGAMATION OF PAINT.

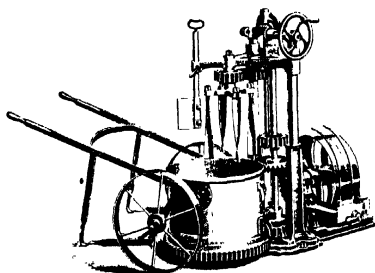


FIG. 10.—MIXER FOR FINISHING PAINT.

in small quantities, the paste is stirred by hand with the added extra medium (say oil, turpentine, and terebine).

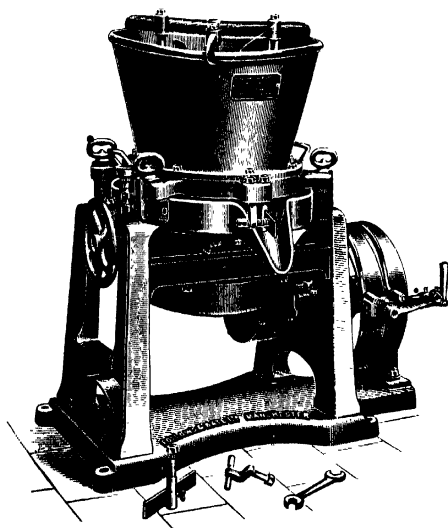


FIG. 11.--CONE MILL FOR GRINDING THIN PASTE AND READY-MIXED PAINT.

(See also Fig. 12.)

A still simpler process is that in which the ingredients are mixed into a thin paste in suitable simple mixers, ground through cone mills (Figs. 11 and 12, pp. 51, 52), and thinned



out to completion in a second simple mixer (Fig. 9, p. 50).

For very fine grinding of "enamels" special

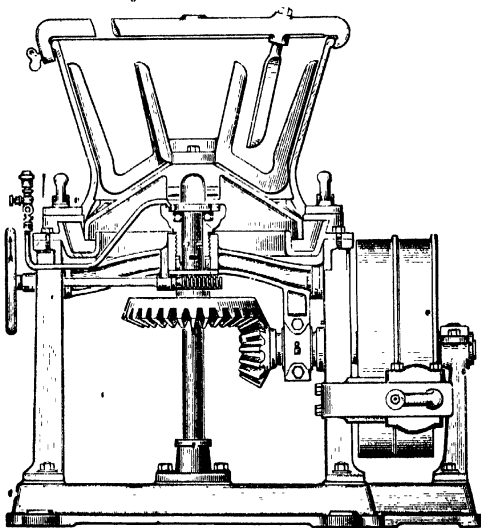


FIG. 12. -SECTIONAL VIEW OF "UNIVERSAL" CONE MILL (AS IN FIG. 11).

flat-stone mills, fitted with water cooling, may be employed (Fig. 4, p. 40), or the pigment may be ground very carefully in good roller mills with a thin oil and afterwards mixed with the special more viscous varnish medium required to complete the enamel recipe.

## CHAPTER IV

### PIGMENTS AND SOLID FILLERS

**35. General Requirements.** Any material which can be obtained in a sufficiently fine state of division—that is, of a size such that the largest particles are smaller in their largest dimension than the thickness of the paint coating (§ 31) in which they are to be used—could be employed as a pigment, subject to the following provisos in addition. It must not be sufficiently soluble in the medium or react with it to modify the properties of the mixture, to too great an extent. For nearly all purposes other properties are necessary, such as insolubility in water, non-volatility, and a certain degree of permanence when exposed to light, oxygen, carbon dioxide, etc.

The commonly employed pigments all conform more or less to these obvious necessities but vary appreciably in this respect. For example, zinc oxide (§ 37) and basic lead carbonate (§ 40) will react to some extent with oil media, especially when resins are present, modifying the nature of the liquid paint sometimes in a way and to a degree which is considered desirable (§ 31), but sometimes to such a degree as to render the paint, after the lapse of time, unsuitable for application to a

surface. Whiting (§ 48) (calcium carbonate) will react in a similar manner and is poor in its resistance to atmospheric influences ; also,

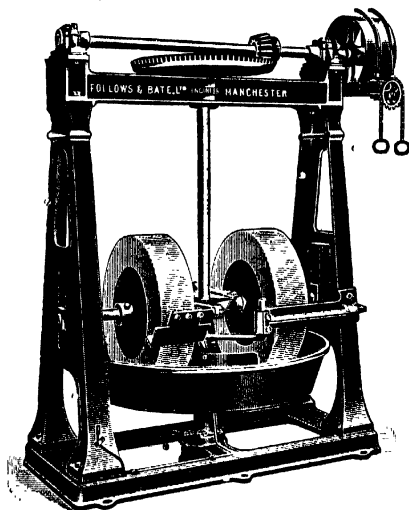


FIG. 13.—EDGE-RUNNING MILL,  
ROTATING PAN TYPE.

For grinding dry colour, etc.

it will dissolve in water which contains carbon dioxide. Barium sulphate (§ 43) is practically insoluble in water, and is uninfluenced by any ordinary conditions, but calcium sulphate (*terra alba*, § 49), is appreciably soluble in

water and commercial barium sulphate sometimes contains this. These differences, advantages and deficiencies are discussed further under the headings of the separate pigments.

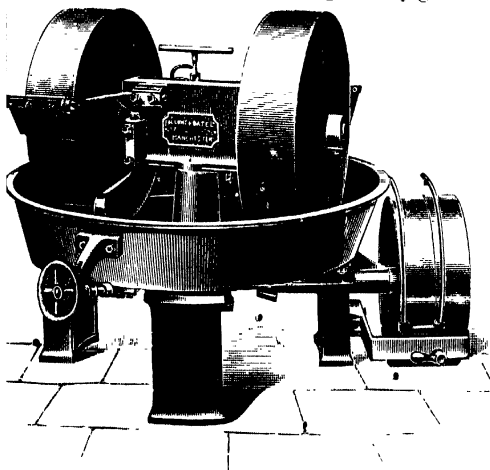


FIG. 14. IRON EDGE-RUNNER MILL,  
ROTATING-ROLLERS TYPE.

For grinding dry powder.

**36. Physical Characteristics of Pigments.** The regular pigments differ in appearance by virtue of variation in hue (colour), purity (brightness), opacity (of which the opposite is transparency), and smoothness (fineness and regularity of the particles).

Oil absorption (the amount of oil by weight required to make with the pigment a soft, paste) depends upon the shape of the particles,

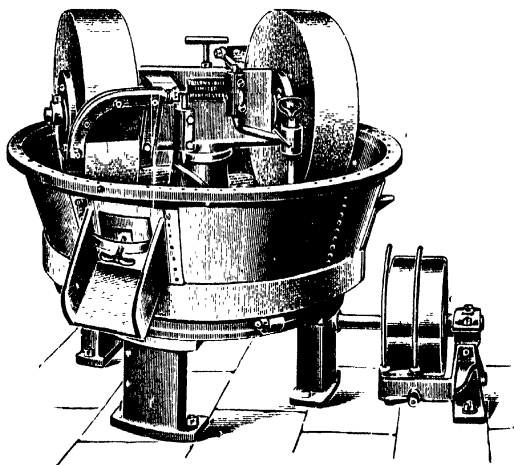


FIG. 15.—GRANITE EDGE-RUNNER MILL  
ROTATING-ROLLERS TYPE.

For grinding dry powder.

their size, and their specific gravity (see Table III, § 33).

Thus china clay (§ 45) with a specific gravity about one-half that of barytes requires not twice the weight of oil that barytes does (per lb. of pigment) but *much* more, owing in part at least, to the finer state of division of the clay.

**37. Zinc Oxide.** This is an opaque white pigment of very smooth texture, and bulky in powder form. It is manufactured by distilling spelter or zinc ores and allowing air to mix with the hot gaseous metal, whereby a fume of the oxide is produced. Sometimes it is made by precipitating zinc solution by means of sodium carbonate or hydrate and calcining the product.

Its white colour in the best grades is very pure and unrivalled by any other pigment; this is one reason for its use in white enamels (§ 30; for another reason *see* § 31). The best grades are 99.9 per cent pure zinc oxide, the usual and chief impurity being a trace of lead sulphate. Lower grades are priced chiefly according to the purity of the colour. Sometimes the oxide is treated with a trace of ultramarine blue (§ 59) to convert a reddish or yellowish tinge to a greyish one, but although this improves the "whiteness" of the pigment at a superficial glance, yet in reality the shade is darkened by the treatment.

**38. Leaded Zincs.** When the ore from which zinc oxide is made contains lead (usually as the sulphide galena) the fume produced, when the gasified ore is burnt by admitting air, contains a proportion of lead sulphate or basic lead sulphate which may be as high as 30 per cent. Such "leaded zincs" are often of

very good white colour, of opacity approaching that of the purer zinc oxides and yield very durable paints with linseed oil, which have been found to compare with those made by an admixture of normal zinc oxide and basic carbonate white lead. They are largely made and used in America.

**39. Lithopone.** This is an opaque white pigment, usually of very good purity of colour. It is composed of barium sulphate and zinc sulphide in intimate association, and is manufactured by precipitating a solution of barium sulphide (from reduction of heavy spar) with zinc sulphate, the mixture reacting to form insoluble barium sulphate and insoluble zinc sulphide. It owes its opacity, which is on a par with that of zinc oxide, to the zinc sulphide content since barium sulphate is transparent in oil. Its opacity is greater than would be expected if the zinc sulphide and barium sulphate were merely present as a mixture and, in explanation of this phenomenon, it has been suggested that each particle of the pigment consists of barium sulphate completely surrounded by zinc sulphide (i.e. adsorbed). Lithopone is usually 30 per cent zinc sulphide, the rest being barium sulphate, these being the proportions mutually precipitated. Lithopones with an excess of barium sulphate are, however, found on the market. Usually lithopone contains

a small proportion of zinc oxide, formed accidentally during the process of manufacture.

Lithopone finds an extensive use in the manufacture of distempers (§ 83) for interior decoration, owing to its great opacity and pure white colour, in conjunction with the fact that it is normally cheaper than zinc oxide and the other white pigments, and is non-poisonous. There is one great drawback to the use of lithopone in distempers, viz., that it is liable to turn grey on exposure to sunlight, more or less regaining its pure white colour after a period of darkness. This is an extraordinary phenomenon not fully understood. There are lithopones on the market for which it is claimed that this defect has been overcome.

• Lithopone is not considered a good pigment for use in oil paint, as paints made from it perish sooner than when made from other white pigments. If lithopone is used in conjunction with lead pigments there is a possibility of mutual reaction whereby black lead sulphide would be formed, to the great detriment of the colour. However, this combination of pigments does not always lead to disaster, and is sometimes used.

**40. Basic Carbonate White Lead.** This has been the principal opaque white pigment in use over a long period, and it is only in recent years that its supremacy has been challenged.



For many years men sought a substitute for white lead owing to the poisonous nature of all the compounds of lead. No material having all the properties of white lead as a pigment has yet been produced, and probably never will be, as the users of paints are at last beginning to realize that it is deficient in some qualities possessed by other white pigments.

The chief advantage of white lead lies in its close texture when ground in oil so that although its opacity *weight for weight* is less than that of others, nevertheless a paint of easy application made from it will often cover better in a coat equally applied than a paint of equal ease of application made from one of the other white pigments, say zinc oxide. Another property that white lead imparts to paint is that of softness of film both when freshly applied (when it is very soft and thus disadvantageous) and when old, when it is not so hard as with some other pigments, and this is a desirable trait.

\* The disadvantages of basic carbonate white lead are—

(1) Its poisonous nature, causing lead poisoning by inhalation of dust when rubbing down the paint with sand paper, etc., to get a good surface.

(2) The film tends to perish rather more quickly than one containing, say, zinc oxide ("chalking").

(3) It discolours in foul atmospheres by

formation of lead sulphide from the sulphuretted hydrogen in the air.

**41. Basic Sulphate of Lead.** This pigment is similar to the basic carbonate just described, but is not considered to be quite so poisonous. It is made by direct distillation of galena ( $PbS$ ) in a current of air. It is made largely in America, and is believed to be superior to the basic carbonate in resistance to sulphur fumes and in the lasting qualities of the oil-containing coatings in which it may figure.\* Many zinc oxides contain a proportion of this pigment in intimate association (§ 38.)

**41 (a). Antimony Oxide and Titanium Oxide.** These are opaque white pigments, which are not yet fully established in the trade. They are both of very high opacity and are inert chemically, and can therefore be mixed with any varnish medium without thickening it unduly, as sometimes occurs with zinc and lead pigments. Antimony oxide, made by a certain English firm under the trade name of "Timonox," is a very good white colour rivalling the best grades of zinc oxide. Titanium oxide is marketed pure but also in a reduced form in which barium sulphate is incorporated just as in the case of lithopone (§ 39).

\* Reports of the Scientific Section of the Paint Manufacturers of the U.S.

**42. Transparent Fillers.** Having now surveyed the range of opaque white pigments, we come to a consideration of the transparent white pigments. Their transparency is not perfect, and varies from one to another, and according to the medium concerned, depending on the smallness of the difference between their refractive index and that of the medium. While being transparent in oil and spirit, these fillers are opaque to a considerable degree in water, and quite opaque when dry. Some of the series show a perceptible degree of opacity even in oil, but they none of them show a pigment strength at all comparable with the series of opaque white pigments if under the same conditions (*see* Table IV).<sup>4</sup>

As they have little or no obliterating power in oil media and are usually cheaper than the opaque white and the coloured pigments, they have been in the past mainly looked upon as adulterants. This is a false view in most cases, as they perform distinct functions. Thus, some of them, such as china clay, terra alba, asbestos, and whiting, are used to prevent the settlement of heavy and dense pigments, and others to produce a certain degree of roughness in a paint to enable subsequent coats to get a firm hold. Their greatest use, however, is to fulfil the chief functions of pigments in a paint, i.e. (1) to enable the oil to be applied to a vertical surface in a thick enough layer for adequate protection which

would not be possible without them, as the oil would run down; and (2) to form, with the

TABLE IV  
REFRACTIVE INDICES, ILLUSTRATING TRANSPARENCY  
AND OPACITY OF PIGMENTS

SUBSTANCE.	Refractive Index	Difference between Refractive Index of Substance and that of Linseed Oil.	Relative size of Particles	Opacity in Oil
Water	1.33			
Linseed Oil	1.48			
Tung Oil	1.52			
Turpentine	1.54			
Rosin	1.51			
Barytes	1.64	0.16	Relatively large	} Practically transparent
Silica	1.54	0.06	"	
Calspar	1.65 (1.48)	0.17 to zero	"	
White Lead	1.8 (2.00)	0.32 to 0.52	Relatively small	Opaque in layers above 1 gm. per 45 sq. cm. (approx.).
Zinc Oxide	2.0	0.52	"	Opaque in layers above 1 gm. per 30 sq. cm. (approx.).
Zinc Sulphide	2.2	0.72	"	Renders lithopone, which contains 30% zinc sulphide, as opaque as zinc oxide

oil as the cement, a compact layer of resistant material.

These considerations apply only when the opaque or coloured pigment is so strong in obliterating power that it is not necessary to use sufficient of it to fulfil the other functions

of a pigment; the use of the cheaper filler is then advisable. This is seen especially in brunswick green paints where the pigment usually consists of 80 per cent to 90 per cent barytes, the balance being the prussian blue, lead chromate, etc. Similarly, in many red paints, the red oxide of iron used is such a powerful colour that over 20 per cent to 30 per cent is quite unnecessary. White paints will not cover perfectly in one coat, even when the maximum amount of opaque white pigment is used, but such paints may advantageously be diluted with a proportion of barytes or similar material, because at least two, and often more coats are applied to the surface in order to get a thickness of film affording adequate protection; such a diluted paint in two or more coats will obliterate the under surface quite satisfactorily.

There is yet an additional reason in favour of the use of these transparent fillers, and it is that they are quite inert chemically, and so allow the oil which surrounds them to dry normally to ordinary linoleum, which then shows its full resistance to disintegration.

**43. Barytes.** Barytes is a crystalline powder obtained by crushing heavy spar, or mineral barium sulphate. Its fineness depends entirely on the degree of crushing and grinding to which it has been subjected, and some samples are rather gritty. It is perhaps the most widely

used of all paint pigments owing to its low cost and its compact character when ground in a medium. Its compact nature gives to paints containing it: (1) Weight—desired because such paints are sold by weight; (2) a good gloss with but little oil since the compact barytes does not absorb much oil; (3) durability of the dry coating, probably owing to the inert character of the barytes and to the fact that it functions solely as a means for supporting the film of oil on the surface during the long drying period and does not interfere chemically with the nature of the linolyn-containing film (*see* §§ 28, 42).

Barytes is tested for purity of colour by comparison with a standard placed alongside, both piles of pigment being then moistened with white spirit or similar material. The appearance of the dry powder is deceptive because the pigment-strength of barytes is great in the dry state but almost disappears when the material is wetted by a liquid with refractive index approaching its own (*see* § 42). Although the coloured body which causes its discolouration may also be rendered transparent by this means its colour is not removed, and so it becomes noticeable.

**44. Blanc Fixe.** This pigment is barium sulphate precipitated chemically from a salt of barium (usually barium chloride or sulphide) and a soluble sulphate. Chemically it

is the same as barytes, but physically it is quite different. Blanc fixe is an impalpable powder composed of uniform very fine particles, whereas barytes is a very irregular, coarsely crystalline powder as would be expected from its origin. Because of the far greater fineness of blanc fixe it absorbs more oil than barytes, and also possesses a greater opacity (§ 36).

It finds considerable use in place of barytes in enamels (§ 30) where the grittiness of barytes would rule out this substance.

Its power of producing a very good sheen in flat paints or distempers (§ 83) in which it is used is one of its most valuable properties. It should be tested for sulphides which would injure any lead paint with which it might be mixed.

**45. China Clay (Kaolin).** This material is an almost transparent "pigment" in oil. The chemical composition is silicate of aluminium (hydrated), but this fact is of little importance when kaolin is used as a paint-filler, for it is quite inert chemically. It is not, however, physically inert, for it has an exceptionally high content of very small and even colloiddally-sized particles which affect the paint into which it enters, out of all proportion to the amount added. This effect is in the direction of making the paint pasty, causing it to show brush marks (§ 33). Where an excessively high percentage of oil is desired

in a paint this property is useful, as it holds the oil up on a vertical surface when it would, otherwise run down. China clay is used sometimes to prevent a heavy pigment from settling, and to give a finer and better textured paste with certain pigments ground as stiff pastes (for subsequent thinning).

**46. Silica.** This is powdered quartz (silicon dioxide,  $SiO_2$ ) and is absolutely inert. The particles of silica possess sharp angles and for this reason, if for no other, the material is often introduced into paint so that a fresh coat of paint may adhere well to it. The microscopical rough surface which it presents is called "tooth." Silica may be used instead of barytes (§ 43) as a heavy filler, but is not so good as it absorbs more oil thus yielding a paint less dense in texture, and also more costly per cwt.

**47. Asbestine.** This is a transparent "pigment" of fibrous nature, the particles being unusually long. It is silicate of magnesium, and is used to assist in holding in suspension more granular and heavier pigments, which it is well able to do owing to the peculiar structure of its particles.

It finds a special use in so-called fireproof paints as the interlacing of its particles causes the paint to remain upon a surface after all organic binding material is destroyed, thus maintaining a non-conducting layer.



**48. Whiting (chalk, Paris white, powdered marble).** This pigment possesses appreciable opacity in oil and quite satisfactory obliterating power in water, hence its great use in distempers (§ 83).

Since this material is calcium carbonate ( $CaCO_3$ ) it is not inert but is easily decomposed by any acid substance, even by carbon dioxide dissolved in rain water. It is also attacked to a very limited extent by resin and oil acids, when ground into paint. This action is sufficient to cause sometimes a thickening of the paint.

There are several forms of whiting, one being ordinary powdered chalk; another, which is the best as regards density, is made by grinding marble; and a third form is that produced by chemical precipitation - usually as a by-product of some industry such as water-softening, which is carried out by many waterworks.

The whiting must be tested for free lime, because even a small proportion would cause a serious thickening to occur in some types of paint.

**49. Terra Alba (Gypsum).** Though this material is chemically inert it is quite appreciably soluble in water; moreover it contains two molecules of combined water in its crystals ( $CaSO_4 \cdot 2H_2O$ ). These facts make its use less than would otherwise be the case. It is produced in two forms; one, the mineral

gypsum powdered, and the other the precipitated form made as a by-product in several chemical processes by the neutralization of sulphuric acid with lime or similarly.

The first kind is coarsely crystalline, the crystals being flaky and soft, and is used in making lime blue (a mixture with ultramarine), as it does not take away from the brilliancy of the ultramarine colour owing to its particles being transparent lamellae.

The precipitated product is usually in long rod-like crystals which will interlace in the same way as asbestos (§ 47).

Free lime must be looked for in the precipitated form, and its presence should condemn the sample.

Plaster of Paris is a partially dehydrated gypsum which would have the property of absorbing any moisture in a paint vehicle or other pigments with which it was ground and so might prove useful under certain circumstances.

## COLOURED PIGMENTS

**50. Drop Black.** Bone black, vegetable black, and similar blacks are made from different kinds of organic matter.

Carbon blacks and lamp blacks are made by collecting soot from the burning of natural gas, paraffin oil, tar oils, etc., in an insufficiency of air. These are nearly pure carbon.

Drop black, vegetable black, etc., are made by calcining organic matter and so contain the ash of the said organic matter in addition to the carbon.

The chemical composition of the blacks varies from 100 per cent to 10 per cent of carbon, the rest being inorganic matter, which in the case of the true drop blacks made from bones is principally calcium phosphate.

All the blacks greatly delay the drying (oxidation, § 11) of oils and varnishes with which they are ground, providing the carbon content of the paint exceeds a certain minimum, say, 3 per cent of the oil.

This inhibitive action is as yet unexplained. One theory is that impurities, such as tar oils, retained by the carbonaceous pigment are the cause, as it is a well-known fact that tar oils introduced into a drying oil retard or prevent its drying. On the other hand, carbon pigments which contain only a trace of oil extractable by means of ether, and which have been made by burning oils (such as paraffin) which themselves do not prevent oil from drying, will nevertheless act as powerful inhibitors.

It may be that the carbon acts as an anti-catalyst, or it may adsorb the catalytic metal compounds, removing them from the reacting mixture.

Most of these blacks are of a fine deep colour, especially American carbon black from natural gas and drop black from bones. The inferior

blacks have a tendency to a brownish tone, which may be corrected by admixture with prussian blue (§ 58), and this is also done with the better blacks when a blue-black tone is desired in a paint.

The staining power when mixed with say, white, varies greatly, the pure blacks being very strong stainers indeed, and twenty times as strong as those containing a low percentage of carbon.

**51. Graphite.** This mineral is a crystalline allotropic modification of carbon, and is not to be confused with the "carbon" blacks. It often contains large proportions of siliceous matter, which is probably an advantage to it, and it may well be that it owes its value not to the intrinsic worth of graphitic carbon but to the inert matter which the pigment contains. A high percentage of graphite, unless diluted ("reduced") with inert materials, has been shown to function badly as a protective pigment. On the other hand, when properly compounded with other pigments, graphite produces a surface on the paint of such a nature as to give some additional protection to the oil film beneath it.

**52. Oxides of Iron.** There is a large variety of oxides of iron used as pigments. The oxides vary according to whether they come from a mineral source pure and simple, whether

they are prepared by some simple processes from a mineral, or whether they are manufactured as a by-product in some chemical operation. They vary in chemical composition and purity, and very greatly in hue, brilliancy, opacity, oil absorption, etc.

The purest oxides, most brilliant colours and strongest stainers, are obtained from copperas by ignition, in the manufacture of fuming sulphuric acid. The colours obtained vary from a scarlet to a purplish tone, the former being called "Turkey" reds, the latter "Indian" reds. Some mineral oxides yield pigments with colours almost as bright as these, and are also termed "Turkey" and "Indian" according to shade.

Reds are obtained from iron liquors, in many industries, by precipitation with soda and calcining the product. When the iron is in solution as sulphate and is precipitated by lime, the product contains a high percentage of calcium sulphate, and is usually known by the name "Venetian" red. Venetian reds contain about 30 per cent  $Fe_2O_3$ , and are of a bright brick red colour.

Very similar in all respects, except that of colour, are the several grades and shades of brown oxides of iron, varying from yellow-browns to purple-browns. Owing to the dullness of shade they are cheaper than the bright red oxides of otherwise corresponding quality. They are mostly of direct mineral

origin, and are much used in making brown and chocolate coloured paints. Their opacity is good, and their staining power fairly good in the purer grades.

The black oxide ( $Fe_3O_4$ , magnetic oxide) is also used in paint.

**53. Umber.** Umber is an earth colour of rather low opacity, containing about 10 per cent of manganese oxides, and of a greyish-brown shade. When ignited and then called "burnt umber" it has a rich and transparent deep yellowish-brown colour. It contains inert material such as clay, and sometimes organic matter. Its oil absorption is very high.

**54. Ochre and Sienna.** Siennas consist of ferric oxide or hydroxide and inert matter such as clay, and are transparent. They have high oil absorptions. The raw sienna is of a deep golden-yellow colour, and the calcined (burnt) sienna is of a rich brownish-red colour. Ochres are similar in nature, containing a high proportion of clay, etc., but they are dull yellow in colour and fairly opaque. They may contain lead chromate added to brighten them — this should be looked upon as adulteration, although it is a more costly material.

**55. Red Lead.** This is an oxide of lead ( $Pb_3O_4$ ) which often contains a proportion of

litharge ( $PbO$ ), which is possibly the cause of its reaction with acid oils and even with normal linseed oil in which it soon settles and hardens so that such a paint has to be made just before use. Red lead is a bright orange-red colour, and is very heavy and dense yielding a workable paint with a very small proportion of oil. It is much prized as a pigment in priming coats of paint. On iron it may have an inhibitive effect on rusting, owing to its peroxide nature setting up the passive state. It is made by the action of heat and air on litharge ( $PbO$ ). Another form called orange lead, produced from white lead, is a lighter powder of a brighter yellower colour, and lacks the exceptional protective qualities of ordinary red lead. It does not form such a dense paste with oils and does not settle like the heavier red lead. c

**56. Yellow Chrome.** Lead chromate yellows are brilliant pigments of good opacity varying from a very pale yellow (primrose) through "lemon," "middle," and "orange" chrome to a reddish-coloured pigment "Chinese" red or "Derby" red. The composition varies with the colour, the paler varieties containing sulphate of lead or carbonate, etc., the "middle" chrome being practically pure chromate of lead ( $PbCrO_4$ ) and the deeper colours being basic chromates, containing  $PbOPbCrO_4$ .

These pigments are permanent to light but are discoloured by sulphuretted hydrogen, as is only to be expected from their composition. The colour of the deeper reddish types is likely to be spoilt by fine grinding as the full depth of colour is caused partly by the large crystalline formation of these pigments.

**57. Zinc Chrome.** Zinc chromate is a pale yellow pigment of lower tinctorial power than normal lead chromate, and is not so brilliant, reflecting a larger proportion of white light; it corresponds with "primrose" chrome (§ 36) in tint.

It finds a use partly owing to its being comparatively non-poisonous (distempers, § 83) and partly owing to its slight solubility in water rendering it an inhibitor of rust because of its oxidizing nature—chromates are well known inhibitors of rust, inducing the passive state in iron (*see* red lead, § 55).

**58. Prussian Blue.** Prussian blue is a transparent colour of very great staining power. It varies somewhat in tone, but is usually of a very deep greenish-blue when ground in oil. Its composition is complex, being a ferric ferrocyanide, often with a proportion of sodium or potassium in the molecule. Many varieties are very difficult to grind finely enough to obtain the full staining value from the colour, and so it is often precipitated on to barytes,



and is thus diluted and its full tinting value obtained. It is then called Brunswick blue. These blues are permanent to light and acids, but are easily decomposed by alkalis and so are not used in distemper.

Prussian blue tint in conjunction with white lead is liable to fade temporarily when closed in a package, but regains its original tint after painting out: possibly, this is due to temporary reduction, followed by reoxidation.

**59. Ultramarine Blue.** Ultramarine blue is a rather transparent but very brilliant colour (a reddish tone of blue), the staining power of which does not approach that of Prussian blue. It is a double silicate of sodium and aluminium containing sulphur, and is an artificial "lapis lazuli." The sulphur is loosely bound as in sulphides, and is easily freed (as sulphuretted hydrogen) by acids, so that ultramarine blue should not be used with lead pigments. The colour, however, is permanent to light and to alkalis and so is very largely used in distemper (§ 83).

**60. Brunswick Greens.** These greens are composed of varying proportions of Prussian blue (§ 58), lead chromate (§ 56), and barytes (§ 43), according to tone and purity. Owing to their great colour, strength, and brilliancy, they are by far the most largely used greens

in oil paints, and owing to the colour strength of the active ingredients, the percentage of barytes is usually high (up to 90 per cent or higher) and yet such pigments are fully effective when made up into paint. The colour can, of course, be made anything from that of Prussian blue itself (Brunswick blue) through dark bluish-green, middle green, and light yellowish-green to that of lead chromate itself. It is usual to find three grades—dark, mid and light—the actual tones being different for different makers. As a rough guide, the proportions of lead chromate to Prussian blue may be taken as 7 : 3 for dark, 8 : 2 for middle, and 8 : 1 for light.

The colour is found to retain its original hue much longer after application and to possess other advantages if the two coloured constituents are precipitated on the barytes more or less at the same time, and so Brunswick greens although analytically the same as, differ essentially from, a mere mixture of lead chromate, Prussian blue, and barytes. •

• If mixed as a pale tint with white lead, the same temporary fading may occur as with Prussian blue (§ 58) and so such a tinted paint may show temporarily a much yellower hue, regaining its original colour after painting out.

**61. Chrome Oxide Green.** This material ( $Cr_2O_3$ ) is a very permanent green, and is used

for tinting distemper. Its tinting power is considerable, but not so great as that of the Brunswick greens, while it is much more expensive and its tone not so brilliant. The hydrated oxide is more brilliant than the normal oxide.

**62. Lakes.** Lake colours are made by the precipitation of a dye on to a more or less inert base such as barytes (§ 43), blanc fixe (§ 44), china clay (§ 45), alumina, red lead (§ 56), and orange lead. Thus there are produced after drying, pigments which possess the colours and brilliancy of the dyestuffs used, and are, therefore, brighter than most inorganic or mineral colours, which is the chief reason for their existence. It is found that lake colours are much more used in reds than in greens; for example, because the common mineral reds (iron oxides) are not very brilliant, whereas the common inorganic greens, Brunswick greens (§ 60), and emerald green (copper aceto-arsenite) are very clean and brilliant colours.

Some lakes are as fast to light as are mineral colours, but others fade rapidly in sunlight. Some are quite insoluble in oil and similar mediums, but others are not and are said to "bleed." "Bleeding" is that phenomenon seen when a coating containing a soluble dye is repainted, the colour dissolves in the oil of the new coat, diffuses through it and makes

itself visible at the surface of the new coating, modifying the shade if different from its own.

Some dyes, such as eosins, used for lakes (vermillionettes) are acidic in nature and so may form insoluble salts with metals such as lead and barium: others, such as magenta (maroon lake), are basic, and so may form insoluble bodies in combination with acids such as tannic acid: yet others are of a coarse colloidal nature and deposit easily on to adsorbent surfaces such as that of green earth, which explains why such earthy materials are sometimes found as the basis of lakes, when they are otherwise not desirable for their own sake and do not find an extensive use in the preparation of coatings. Thus greens of basic character (brilliant green) may be precipitated on to green earth, and are used in distemper for tinting.

## CHAPTER V

### COATINGS WHICH DRY BY EVAPORATION OF SOLVENTS

COATINGS which dry principally by the volatilization of one or more of the ingredients are of widely differing types, and will be treated in this chapter according to the nature of the solvents employed.

#### TURPENTINE. WHITE SPIRIT. • LIGHT NAPHTHAS

63. **Resins Used.** Coatings using these solvents are made usually with a rosin (§ 79) or rosinate basis; other superior resins are more costly, but have better properties for certain purposes. There may be mentioned here, Kauri, soft Manilla, the various qualities of Damar, and the several copals (§ 15). Kauri requires turpentine (§ 13) as solvent, Manilla can be used with an admixture of alcohol (§ 77) with coal tar naphtha (§ 73) or benzol, while the copals mostly require a preliminary heat treatment and the introduction of some oil to get them into solution (§ 17).

The rosينات used are those of calcium, lead, manganese, magnesium, aluminium, and zinc, the calcium rosinate being by far the

most commonly employed. The object of converting the raw rosin into calcium rosinate is to make a material with a higher softening temperature and hence a less tacky film. This is called "hardening" the rosin. Usually only about one-half the rosin is converted into the calcium rosinate, as a higher degree of combination is difficult to obtain by simple heat treatment.

The rosinate of lead and manganese have been used for the same purposes as that of calcium, and their use follows from their employment as driers (§ 11) for oils and oil varnishes. Thus sometimes they are added to increase the rate of drying of the class of coating under consideration, by false analogy with their action in drying oil vehicles. In the case of coatings which dry by evaporation alone, lead and manganese compounds cannot hasten the rate as they do when acting as catalysers of oils which resinify by oxidation (but see short-oil varnishes, § 66). Lead rosinate may quite logically be used in preference to calcium rosinate, for the sake of its own physical properties, calcium rosinate being less resistant to moisture and, according to some observers, rather easily hydrolysed into free lime and rosin under certain conditions.

**64. Softeners.** Besides the volatile matter and the rosin, rosinate or other resins, it is usually desirable to introduce a softener of

the resins, for they are very brittle and friable after the volatile material has completely evaporated. Such softeners are mineral oils of any suitable quality, rosin oil, varnish fume (§ 17), non-drying and semi-drying glyceride oils such as tallow, rape oil, cotton seed oil, etc., and drying oils such as raw linseed oil (§ 7), stand oil (§ 9), etc. The latter operate as softeners first as liquid oils, which condition they retain for very long periods owing to the deliberate exclusion of driers, and especially if compounds which inhibit their oxidation are purposely added. Drying oils may also act as softeners in the form of the oxidized product linoxyn, in which case a large proportion of lead rosinate, etc., is usually present to bring about the oxidation. This brings us to that class of composition known as gold size (§ 67), short-oil varnish, terebine (§ 68), etc. When the drying oil is still further increased we arrive at the ordinary type of elastic varnish such as copal varnish which is discussed in Chapter II.

Before passing to a consideration of these largely-used coatings in which the softener is finally an oxidized product, it is necessary to note that soft resins (oleo-resins) are sometimes used in conjunction with the hard and brittle ones to achieve the same object as the simple oil softeners already considered. Guttapercha and india-rubber might also be mentioned in this connection.

**65. Manufacture of Quick-Drying Paints, etc.** Most of the varnishes and media considered above are easily made by simple mixing in the cold. A cylinder capable of holding the batch, which may be very large is held in a horizontal position, and a shaft runs along the axis carrying knives which are placed radially at intervals. This shaft is made to rotate at a convenient rate and achieves the solution of the resin, etc., in the solvent in a few hours. The charge is admitted through a hole in the top which can be closed by a lid, and a pipe let into the bottom and fitted with a tap suffices to let out the finished mixture.

Pigments are ground in these media in the same cone mills as are suitable for grinding linseed oil paints. Quick-drying paints are thus produced suitable for special purposes where quick drying is essential and where the special weather-resisting qualities and durability of linoxyn are not required.

**66. Short-oil Varnish.** The remarks in the preceding paragraph do not apply to the mixtures containing linseed oil known as short-oil varnishes, gold sizes, etc. These are always made by processes involving heat, and are very largely used as transparent varnishes as well as for the manufacture of pigment-containing coatings.



Short-oil varnishes and gold sizes dry first by the evaporation of the solvent, and then more fully by the oxidation and resinification of the oil contained therein. The name gold size is applied to some types which are still semi-fluid when the volatile matter has evaporated, and these belong to the type of oil varnish described in Chapter II, although they usually oxidize to a film much more rapidly owing to the very large amount of drier present. There is, in fact, continuous gradation of constitution and properties from a very elastic oil varnish containing much oil at one extreme, to a brittle resinous gold size containing very little oil at the other extreme, and there is no special point at which the dividing line may be drawn. The nomenclature is loose, as is found everywhere in this industry. Generally speaking a short-oil varnish is the same as an elastic copal varnish (long-oil varnish) except for the much smaller proportion of oil, which causes it to present a fairly firm coat by the mere evaporation of the solvent (turpentine or white spirit). Its method of manufacture is the same as that of the more oily varnishes, dealt with in Chapter II.

Short-oil varnishes can be made with a proportion of rosin (§ 79) and are then much inferior in resisting abrasion and atmospheric influences, though their gloss and initial appearance is likely to be improved.

**67. Gold Size.** Gold sizes are of very differing types, some made with copal (§ 15), some with rosin (§ 79) as basis, but nearly all have a large proportion of metallic drier (§ 11) incorporated. The name follows from the use of such varnishes for sticking gold leaf to surfaces. For this purpose the gold size is applied and then allowed time to become tacky before the gold leaf is spread upon it. By restricting the application of the gold size to the exact portions of the surface which it is desired to coat with gold, the leaf is made to adhere only to such portions and may be trimmed off at the edges.

**68. Terebine.** "Gold sizes" are now used for a variety of other purposes, the name has lost its original significance, and the varnishes which come under this heading vary greatly. Some are practically short-oil copal varnishes, as previously described, without a very great amount of drier, others largely consist of rosins (§ 79) of the drying metals, and their principal use is to be mixed with linseed oil to cause it to dry. Such gold sizes when so used are better termed terebines. Terebines are solutions of metallic rosins, linoleates, oleates, etc., in white spirit or turpentine, and are used solely as a convenient means of introducing the metal catalyst into drying-oil and mixtures or varnishes which contain drying oil. They are usually made of

a lower viscosity than gold sizes in order to facilitate their amalgamation with the oil or to deter the user from adding too great a quantity. This thinness, however, is not necessary or even desirable. Should too great a quantity of terebine, containing rosin, be added to a paint or varnish it may be bad for the durability of the film. The metals present as driers are lead, manganese, and (or) cobalt (§ 11).

Here again we find a looseness of nomenclature and a gradation of characters without any definite dividing line between varnishes, gold-sizes, and terebines.

.. **69. Uses of Gold Size.** The original use of gold size and one for which it is still required is for the application of gold leaf and other metallic leaves as described in § 67; or for giving a similar effect by dusting on metallic powder. Other common uses are:

(a) Mixture with paints containing linseed oil, to cause the oil to dry and to give a harder coat. For this purpose, the gold size must be of that sort which contains much rosin or linoleate of lead, etc.

(b) Making quick- and hard-drying paints for coach builders' use (§ 5), as undercoats. These paints dry flat in appearance and admit of rubbing down. In this instance the high class gold size, containing the best copals and no rosin, is best; and the copal used and the

method of manufacture must be such that the gold size will not feed, i.e. thicken unduly, with basic lead carbonate or with zinc oxide.

(c) As a medium for metallic powders, like aluminium powder, which require a medium which will hold the powder tenaciously even before the drying oil (if such is used in the mixture) has had time to oxidize, especially as the metallic powder sometimes will exclude air and greatly delay the oxidation. In this case also a high class gold size is desirable, which will not react with the metal of the powder, dulling its appearance and causing it to clot together. The free acid should be kept very low, if necessary by addition of lime during the manufacture of the gold size.

(d) As a varnish where quick-drying is very desirable but durability not important, as in cheap stains for domestic use (§ 2) when a bright varnish finish and a stain is required in one application.

**70. Substitutes for Linseed Oil.** Certain types of the class of coating considered in this chapter happen to be much cheaper to produce than those containing linseed oil and the various modifications thereof, and, so we find types, which are made to imitate linseed oil paints in their rate of drying—the rate of evaporation being prolonged purposely to simulate the behaviour of oils which dry by

oxidation. Such mixtures are used as substitutes for linseed oil, and are made up into paints which behave more or less like true linseed oil paints in application, smell, appearance, etc., but which have not the protective quality of the genuine article, since the resin which remains when all the very slow volatilizing ingredient has gone, has not the durability of the oxidized product left from the oxidation of drying oils. Moreover, the percentage of resin left is only about 60 per cent of the "oil" (the rest being volatile) whereas the proportion of oxidized product of linseed oil left in the paint film is actually more than the oil originally introduced. This distinction is shown clearly by Table V. The durability of a paint is largely dependent upon the ratio of binder remaining in the dried film and the superiority of linseed oil paint in this respect, apart from the greater durability of linnoxyn compared with resin, is shown by the Table.

• The resin for such substitute paints is often common rosin with or without the addition of metallic rosins, such as those of lead and manganese, which are sometimes added for mere camouflage—colour and analysis. There is, as a corporate part of the resinous residue, a non-volatile non-drying oil such as mineral oil (as is used for lubricating),\* the presence of

\* See also *Lubrication and Lubricants*, by J. H. Hyde. Uniform with this volume. (Pitman, 2s. 6d. net.)

which prevents the resin from becoming too friable and brittle. Rosin alone quickly becomes so friable that on rubbing gently it will dust away as though it were a powder already ; the oils added cannot altogether prevent this tendency of the rosin. Other softening oils

TABLE V  
COMPARISON BETWEEN LINSEED OIL PAINT AND  
RESIN SUBSTITUTE PAINT

	Both Paints when Wet.*	When Linseed Oil Paint.	Dry. Resin Substitute Paint.
<i>Parts, by weight —</i>			
“Oil” . . . . .	30	35	20
Pigment . . . . .	65	65	65
Turpentine added to get easy working under brush . . . . .	5	—	—
<i>Ratio, Oil : Pigment</i> .	6 : 13 or 46%	7 : 13 or 54%	4 : 13 or 31%

\* The substitute paint is compounded to imitate the linseed oil paint when wet.

which may be added are rosin oil, varnish fumes (§ 17), varnish foots, oil foots—in fact any non-volatile oil which will form a homogeneous mixture with rosin.

From the foregoing it must not be thought that such linseed oil substitutes are without

any protective value. If carefully proportioned and made up into paint they will produce coatings of quite unexpected durability, especially for inside use. Their appearance is satisfactory at first, but there is a tendency to poor gloss owing to the low proportion of residual oil and resin, and to the development of surface cracks and markings.

The volatile matter used is white spirit (§ 14) of low quality, i.e. having a long "tail"—a large proportion of difficultly volatile matter as shown by the distillation test. This grade is used, because it is cheap and owing to the presence of additional difficultly volatile matter which is desirable in this instance; the low quality is thus no detriment. The difficultly volatile portion may be the petroleum distillate lying between white spirit and lubricating oil, sometimes called gas oil, or other similar product, also the non-volatile and the difficultly volatile may be added as one single ingredient. Some types of varnish fume (§ 17) are partially volatile, partially non-volatile oil, and partially resin or the residue becomes resinous on exposure to the air. It is not possible in such substitute oils to decide where the volatile ends and the difficultly volatile begins; where the difficultly volatile ends and the non-volatile oil begins; and where the non-volatile oil ends and the resin begins. The blendings possible to attain the desired effect are legion.

Points to be taken into consideration in addition to those outlined already are—

(1) The oil must be capable of being used with either lead carbonate (§ 40) or zinc oxide (§ 37), without combining with either to form a solid, or too stiff a paste.

(2) Paint made with the oil must be able to contain a large proportion of barytes (§ 43) without settling down hard. This is necessary as these paints must be cheap and barytes is an ingredient which greatly conduces to this end.

(3) Generally speaking, the maximum durability of a substitute paint is obtained when the "non-volatile" oil is of such a nature that it volatilizes, resinizes, or otherwise disappears as slowly as possible, thus continuing to function—for it must be remembered that the term non-volatile oil may be only relative, and that in time resins originally containing heavy oils will be found to have become brittle. On the same score, this ingredient should be present in a proportion as high as possible without causing other faults such as stickiness and undue softness.

(4) If high gloss is required the proportion of non-volatile oil in the mixture must be low and the resin high as the glossy surface must be hard enough to withstand touching with the finger without marking—such "enamels" are made and dry quickly with a very good appearance, but they are very brittle and are useless out of doors.



## BITUMINOUS COATINGS

• **71. Black Bitumen Coatings.** There are two fairly distinct varieties of black coatings which owe their blackness to the type of resin used and not to added dry pigment, as in the case of black paints proper. In one group, coal tar pitch, and coal tar oils are employed; and in the other, the principal constituents are bitumens originating in the refining of petroleum or of a direct mineral origin. Coatings in the first group do not lend themselves easily to admixture with ingredients not of a coal tar origin, though such other ingredients can be and are sometimes added in small proportions. Moreover, these coatings do not admit of the addition of drying oils, for the coal tar compounds inhibit the formation of linoxyn, etc. The coal tar pitch is not easy to get into satisfactory solution, and it is easily thrown out again at small provocation, such as by injudicious additions to the varnish. This class is used principally as cheap black coatings for exposed ironwork for which purpose they have proved very satisfactory (§ 4).

**72. Coatings with Petroleum Base.** These coatings do allow of the addition of drying oils, for the bitumens of petroleum origin do not interfere markedly with the drying of linseed oil. They may also be used in conjunction with copals (§ 15) and will dissolve in volatile

solvents of coal tar extraction and also in many others, such as white spirit, turpentine, rosin spirit. These bitumens lend themselves to a considerable variety of purposes. Some are compounded to compete with the coal tar type of coating for protection of ironwork in exposed situations and where under the destructive influences of acids, water containing electrolytes, etc. Other recipes are designed to yield coatings with a very high gloss and fine appearance, but without much strength or lasting qualities, known as Brunswick blacks which find a use in the home, to give a bright black finish of a more or less temporary nature to domestic utensils, stoves, etc. These blacks may contain rosin (§ 79) to give gloss, and bone pitch to give a deep black. The mineral bitumens or asphalts of the highest quality, such as gilsonite, form part of many black enamels, containing much drying oil, which first dry by the evaporation of the white spirit or turpentine contained and then harden by the oxidation of the linseed oil or other drying oil. Black enamels such as these usually contain added black pigment since the proportion of dark-coloured asphaltum is not sufficient to give the required opacity.

**73. Coatings with Coal Tar Base.** In these coatings coal tar pitch is the base and coal tar naphthas are the volatile solvents. The pitches from coal tar vary greatly among themselves, according to the method by which the coal has

been carbonized, and (though not so much as might be expected) according to the source of the coal from which the tar has been distilled. Coal tars are distilled and yield benzole, the coal tar naphthas of graduated boiling points, naphthalene, anthracene, anthracene oils, and pitch. The pitch from horizontal and inclined-retort tar usually contains a high percentage of free carbon, about 50 per cent, which gives to it a pasty consistency after it has been softened by heat, and this same pasty effect is seen in the black varnishes made from it. In view of this free carbon pigment, such black coatings should properly be called paints. The pitch from vertical-retort tar contains a much smaller percentage of free carbon, about 25 per cent, so varnishes made from it flow more freely than those from the inclined-retort coal tar pitch. Pitch of similar character to these is obtained from water-gas tar, but its content of carbon is very low, and it is likely to partake more largely of the nature of petroleum asphaltum, especially when coming from carburetted water-gas.

By combining the various pitches with tar, anthracene oil (green oil), and the various coal tar naphthas a great number of recipes can be prepared, without going outside the products of coal tar. Coatings of this type differ rather widely in their ease of working, rate of drying, appearance when fresh and

appearance when old, and in their protective value. The protective quality is usually high, in spite of the cheap source of the ingredients, and is higher than that of many coatings costing much more.

These varnishes are incompatible with oil paints and varnishes, and if used over fresh oil paint will soften or even dissolve it. One or two coats of the bituminous solution alone should be applied.

### ALCOHOLIC VARNISHES

**74. Shellac.** The principal resin of those which yield varnishes with alcohol is shellac. This is the product of an insect which lives in India, and coats with resin the twigs of the trees on which it swarms.

- Shellac is a very valuable material owing to its extremely tough nature ; it is hard enough to resist much abrasive action, and is not very brittle. It forms a film, left after the evaporation of an alcoholic varnish, which will entirely resist the thumb nail. Shellac comes into the market in several forms, most of which contain a small percentage of rosin (§ 79), which is said to be added to facilitate the refining process, making the shellac melt more easily, but which is also added as an adulterant since the cost of shellac is so high and that of rosin so low.

Crude shellac is deeply coloured red with the lac dye which is another product of the same insect and various expedients are used to

decrease or eliminate this colour. Garnet lac usually contains rosin, is deeply coloured, and is sold in thick pieces (also moulded and then called button lac). Standard T. N. Shellac usually contains not more than 3 per cent rosin, and is of a pale orange colour; it is sold in rather thin flakes. Lemon Shellac is similar but much lighter in colour.

Bleached Shellac is quite colourless, the last traces of dye having been destroyed in a process of bleaching with chlorine, which incidentally considerably modifies the nature of the shellac itself. This bleached product contains water (the process necessitates precipitation from an aqueous solution) and it is a strange fact, that the lac is only soluble in alcohol so long as it is still in this moist condition, for if it is dried or kept too long it becomes insoluble in alcohol or indeed in any solvents, and will only swell therein. Carelessly made qualities show a tendency to softness and stickiness, especially when the varnish film is warmed.

There are many other less definite grades of lac on the market.

*Tests.* Since shellac is liable to adulteration with rosin it is important to know if this is present and if so, the proportion. The quantity of rosin is estimated from the iodine value of the resin since that of rosin is very high (about 230) while that of shellac is very low (about 18).

Shellac is easily dissolved in alcohols, ethyl alcohol (i.e. methylated spirit) or methyl alcohol (i.e. wood spirit) in any plant which provides sufficient agitation, which is so designed that the alcohol will not be allowed to evaporate rapidly, and in which there is no danger of fire or sparking. A horizontal cylindrical mixer is suitable.

**75. Usefulness of Shellac.** The proportion of shellac required to make a varnish of convenient consistency for brushing is about 35 per cent, which is much lower than that of most other resins in alcohol or white spirit, naphtha, etc. The coating yielded by a shellac varnish is therefore thinner than that yielded by most of the others, nevertheless its resistance to scratching, rubbing, etc., is much higher than that of the others. The shellac film, however, is not very resistant to atmospheric influences, and will slowly absorb moisture, turning white. This latter effect is less likely to be found where the shellac has been baked on, or is very old. Thus a shellac film is not suitable as a protective coating out of doors, but is very satisfactory for articles which are much handled indoors, as its film is absolutely non-tacky.

Most of the lacquers found on metal articles are of shellac baked on—the articles having been coated with the shellac solution while warm and dried in a warm, moisture-free

atmosphere, and then baked for a short time at a low heat.

The shellac film is insoluble in most of the ordinary organic solvents and so shellac varnish finds an application as a medium for paints resisting petrol, benzol and naphtha ; for which purpose, pigments, the same as those used with linseed oil media, are ground into the shellac varnish, or metal powders such as aluminium powder are mixed in, where such a metallic effect is required.

**76. French Polish.** Most articles of furniture (§ 5) are coated with a thick, firm, glossy crust of resin, which should be pure shellac, that has been applied in the special manner known as French polishing.

In this process of application a thin shellac solution in alcohol (about 1 to 10) is rubbed over the wooden surface by means of a pad of cotton wool wrapped in a small piece of soft non-fluffing fabric. The soddened pad is passed quickly over the whole area of the article to be coated touching each part once only—then when this very thin coat has hardened, which takes place quickly, the pad is again swiftly and dexterously passed over the surface. This is repeated many dozens or even hundreds of times until a good thickness of resin results. It is necessary to moisten the pad with raw linseed oil (§ 7), to allow it to slip over the surface satisfactorily, but very

little must be used. The resin layer is rubbed down with pumice as many times as is necessary to get an even grainless surface. The final polishing which yields the splendid finish of French polish calls for great skill and is completed with clean pads, very slightly moistened with alcohol, which are first rubbed very lightly and then more heavily over the surface, continually adding traces of alcohol to the pad until all oil is removed from the resin surface.

**77. Soft Manilla.** Manilla varnishes are largely used where shellac (§ 76) would be too expensive, or where greater gloss is required than shellac would afford, when applied by brush. Manilla varnish takes the place of French polish in cheaper articles of furniture, bannisters, rails, etc. (§ 5). It will allow of handling without showing tackiness, and has a fine appearance. It has, however, the same defect as shellac, in turning white by absorption of moisture and it is therefore useless for outdoor application. It is not suitable for mixing with any but the inert pigments, as the acids of this varnish are very reactive, thickening up with basic pigments and corroding metallic powders. Manilla varnish is paler in colour than shellac varnishes, excepting varnish made from bleached shellac.

**78. Sandarac.** This resin is pale and dissolves easily in methylated spirit. Its uses



are much the same as those of manilla and shellac. It is rather weak and brittle, and is used for mixing with shellac in brush varnishes or polishes as they are called, to cheapen the product and to give more gloss and a clearer and thicker film.

**79. Rosin.** Rosin or colophony is used in alcohol varnishes for cheapness, and to give gloss, but it always greatly reduces the strength of the resultant coating. It is not used alone, as it is equally soluble in cheaper solvents than alcohol, and of course these would be used in preference, if ever a simple rosin solution were wanted.

Rosin is a highly acid, extremely brittle resin obtained as a residuc when turpentine is distilled off from the oleo-resins of pines. The metallic salts are known as rosinates. Its combining weight may be taken to be about 350. It is very largely used in conjunction with linseed oil, etc., for making varnishes, and in quick-drying coatings using white spirit as solvent (*see* § 63).

### CELLULOSE VARNISHES

**80. Nitro-Cellulose.** Collodion and celluloid require a proportion of ketonic or ester solvents in the mixture which is to bring them into solution, and even then only a comparatively small proportion can be dissolved, if a solution not too viscous for brush application

or dipping is to be obtained. A 10 per cent solution in the case of collodion or celluloid (estimated on collodion content) is about the maximum for brushing—5 per cent makes a quite fluid solution, and will actually yield a better coating than the 10 per cent solution owing to the latter dragging and pulling up after the brush, leaving streaks and patches almost uncovered. The above percentages are only intended to be suggestive, since the viscosity varies greatly with the particular mixture of solvents used, and these figures will apply to the better mixtures of solvents rather than to the inferior.

*Collodion* is nitro-cellulose, and is made by the action of concentrated nitric and sulphuric acids on cotton or other kinds of pure cellulose. The forms containing fewer nitro groups are usually called collodion, and those containing more are called guncotton and used as explosives.\*

*Celluloid* is made from all types of nitro-cellulose, and is nitro-cellulose with which has been incorporated a proportion of a compound to reduce its explosive or inflammable nature. The safety ingredients may be added in solution, in which case collodion is first dissolved and the collodion solution thus transformed into a celluloid solution; or they may be

\* See also *The Manufacture and Uses of Explosives*, by R. C. Farmer. Uniform with this volume. (Pitman, 2s. 6d. net.)

incorporated by mastication with but a small proportion of solvent. The compounds used for this purpose are very diverse.

*Camphor* is commonly used but, not unexpectedly, has the objectionable feature of imparting its odour to the celluloid. *Camphor* is the product obtained from the *Laurus Camphora* of Japan. It can be made chemically from turpentine, but the natural *camphor* is the commercial article. Some other compounds used for the same purpose as *camphor* are castor oil, naphthalene, triphenyl phosphate and cellulose acetate.

Suggested recipes for cellulose nitrate varnishes are given in Table VI.

TABLE VI  
VARIOUS RECIPES FOR CELLULOSE NITRATE  
VARNISHES

	Parts by Weight.				
	(a)	(b)	(c)	(d)	(e)
Cellulose Nitrates . . . . .	5	5	5	5	5
Acetone . . . . .	—	—	—	35	—
Amyl Alcohol . . . . .	—	—	30	—	—
Amyl Acetate, or Ethyl Acetate . . . . .	—	95	35	20	35
Methyl or Ethyl Alcohol . . . . .	50	—	—	20	30
Ether . . . . .	45	—	—	20	—
Benzol . . . . .	—	—	30	—	30
Camphor, etc. . . . .	As required.				

*Solvents for Cellulose Nitrate Varnishes.*  
Amyl acetate (pear oil) is a powerful solvent and

may be used alone. Its low volatility makes any varnish, containing a good deal of it; dry slowly and evenly, but its odour is very strong and characteristic.

Amyl alcohol (or mixed alcohols, fusel oil) can replace the acetate to some extent, and operates in the same way in making the varnish more tractable; its odour is also objectionable.

Ethyl acetate is similar to amyl acetate, but not so effective, as it is more volatile and not such a good solvent. On the other hand, its odour is less powerful.

Ethyl alcohol or methyl alcohol, or the mixture methylated spirit, will not dissolve celluloid, nor will ether; but the two together, ether and alcohol, will dissolve celluloid. Ether or alcohol may be used as diluent after the celluloid has been dissolved in amyl acetate.

Ether thins out a solution more easily than any of the other solvents, and this is its function when added, but this result may easily be rendered ineffective owing to the very rapid evaporation of the ether during application.\* Moreover, this rapid evaporation causes cold and thus leads to deposition of moisture on the drying varnish, with a great risk of spoiling the film, or making it opaque. Other solvents which can be used in moderate proportion are turpentine, white spirit, acetone oils, chlorhydrin, acetic acid.

\* Ether boils at 35° C. (95° F.).

**81. Uses of Cellulose Nitrate Varnishes.**

These varnishes are used for coating articles which are to be much handled, as the film obtained is very tough, not easily scratched, and not softened by grease or moisture. They are also used for a large variety of minor purposes, such as—

(1) Lacquering metals with a colourless solution which hardly changes the appearance of the metal.

(2) Colouring glass, metals, etc. In this case a suitable dye (soluble in the solvents used, i.e. spirit soluble) is added to give the desired effect. Small electric bulbs are dipped in such solutions for decorative effects or to produce photographic ruby lights.

(3) Impregnating gas mantles to hold together the very delicate threads, of oxides of cerium and thorium, during transit and handling.

(4) As a coating for small wounds and cuts to keep dirt out and allow quick healing.

(5) As a dope for aeroplane wings—though the other cellulose ester, cellulose acetate, is much more largely used for this purpose.

(6) As a medium for powdered metals such as aluminium powder—though the low proportion of cellulose nitrate that can be got into solution does not enable it to bind a large percentage of the powder satisfactorily.

Nitro-cellulose varnishes are not easily applied with a brush unless only the slowly

evaporating solvents are present and, as a thick layer of liquid varnish is desirable in order to obtain an appreciable thickness of the dry cellulose nitrate film, it is usual to coat objects by dipping or by pouring the varnish over the object and allowing it to drain.

**82. Cellulose Acetate.** Varnishes of which this is the solid ingredient are made using mixed ketonic alcoholic and ester solvents. Their principal use, and one for which they are considered pre-eminent, is as coatings for aeroplane wings ("dope"). They possess the valuable property of shrinking the fabric, so making it taut to an unusual degree.

## DISTEMPERS

**83. Simple Distemper.** A distemper in its simplest form consists of glue (size), water and whiting (§ 48), which is sometimes called "whitewash," and is often tinted bluish with ultramarine blue (§ 59).

It can easily be seen that using whiting (which is very cheap) as the chief pigment in high proportion, water as the volatile matter and glue as the binder, a very cheap coating is obtained with much to recommend it on the score of appearance. It will cover up ugly or dirty surfaces more effectively than will oil paint; it is very easily applied with large brushes owing to the low viscosity of the medium; and, under such conditions, it can

be applied quite thinly and rapidly, and therefore cheaply. This, in conjunction with the very cheap ingredients, makes it possible to cover large surfaces at very low cost. Moreover, these considerations make it possible to recoat at fairly frequent intervals, and so cleanliness and good appearance may continually be maintained. Distempers are especially suitable for use on rather absorbent surfaces.

The defects of distempers are as obvious as the advantages. The coating is not impervious to water, and so has low protective value. Where much water is present it will become soft and may wash off. Where the atmosphere is damp the size will putrify (unless much preservative has been incorporated) and then the whiting, having lost its binder, will easily rub off or even dust and flake off of its own accord. This is often seen in dwellings, especially in the sculleries where intermittent dampness favours the disintegration.

Distempers of this simple type are sold cheaply, usually in powder form, to save the cost of a watertight package and the additional transport charges. In these cases the glue is in the form of a fine powder intimately mixed with the pigment and thus rapidly swells and goes more or less into solution when the powder distemper is mixed even with cold water. The powder is mixed and ground in edge runner mills, *see* Figs. 13-15, pp. 54-56.

**84. Casein.** Casein may be substituted for glue in powder distempers in which case a little alkali is present as casein is not soluble otherwise. When casein is used the resulting coating cannot easily be washed off, but it is more friable and liable to rub off or be easily scratched off when dry. The resistance of the film to water, when once it has been thoroughly dried, is due to the insolubility of casein in water. When mixing the distemper, the casein is got into solution by the aid of an alkali, such as hydrate of calcium (slaked lime). After the coating is applied, the alkali is neutralized gradually by the carbon dioxide of the air, being converted into chalk (calcium carbonate) which has not the power to assist the casein into aqueous solution. Such a distemper would allow of a certain amount of sponging and washing down, and might be termed a washable distemper (§ 85).

**85. Washable Distemper.** More elaborate distempers are made containing additional ingredients to improve the properties in several directions.

For instance, washable distempers and sanitary distempers are pastes of glue, water, linseed oil or copal varnish, preservative, and disinfectant, with a high percentage of whiting (§ 48), lithopone (§ 39) or other pigments ground in.

Since they contain oils, etc., these distempers



are sold in paste form only. The paste is usually soft enough to allow of its being mixed cold and by hand, with the requisite amount of cold or luke-warm water to thin it to a suitable consistency for use. From some points of view it is desirable that the proportion of glue should be low ; for instance, so that the paste is not very gelatinous, but owes its modicum of rigidity partly to the high percentage of pigment, thus allowing it to be mixed with water cold. If the glue were in sufficient proportion fully to gelatinize the mass then water could not be mixed in to thin it until it had been made fluid by heating. With such a distemper it is necessary to place the keg in a pail of hot water before thinning, and to use hot water for thinning.

The linseed oil (§ 7), etc., has the effect of increasing the resistance of the film to water, and operates also as an additional binding agent. As the water evaporates out of the glue, the oil which has hitherto been present in an emulsified form, oozes out on to the surface of the glue film and partly protects it from moisture. It might be expected that the oil in drying would harden the glue by the aldehydes evolved, but the evidence is against this.

However, in spite of such palliatives and in spite of the name "washable distemper," such paste distempers as described will rarely stand more than gentle sponging.

The disinfectants used are of more importance than might at first appear. Their first function is to preserve the paste, and their second is to prevent putrefactive decomposition of the glue, etc., after application to the surface. In addition, they disinfect the walls to which the distemper is applied. Without a proper proportion of suitable disinfectant, the distemper would be better termed "insanitary" rather than "sanitary" distemper.

The manufacture of distemper is carried out in the same way as that of oil paint, the medium being, of course, a watery one. The medium is first made up completely, including the emulsification of the oil, and the pigment is then ground in it. As an example of a water paint recipe the following will serve—

		Per cent by weight
Glue . . . . .	.	5
Linseed Oil . . . . .	.	5
Water . . . . .	.	35
Lithopone . . . . .	.	55

Disinfectant and stainer are added to the mixture as required and, for cheapness, the lithopone may partially be replaced by whiting.



## BIBLIOGRAPHY

For additional information the reader may be referred to the following publications—

- Oil and Colour Trades Journal* (published weekly).  
*Proceedings of the Paint and Varnish Society.*  
*Proceedings of the Oil and Colour Chemists' Association.*  
*Painters' Colours, Oils and Varnishes*, by G. H. Hurst. (Griffin.)  
*Chemistry and Technology of Paints*, by Maximilian Toch (Crosby Blackwood.)  
*Paint Researches*, by H. A. Gardner. (Judd & Detweiler.)  
*Analysis of Paint and Varnish Products*, by C. D. Holley. (Wiley.)  
*Chemistry of Linseed Oil*, by Newton Friend. (Cluney & Jackson.)  
*Paints and Varnishes*, by A. S. Jennings (Pitman.)  
*Oils*, by C. Ainsworth Mitchell. (Pitman.)  
*Coal Tar*, by A. R. Warner. (Pitman.)  
*Gums and Resins*, by E. J. Parry. (Pitman.)  
*Petroleum*, by A. Lidgett. (Pitman.)  
*Treatise on Colour Manufacture*, by Zerr, Rubencamp & May. (Griffin.)

The under-mentioned Technical Primers, uniform with this volume (Pitman, 2s. 6d. net), deal with subjects bearing more or less directly upon the operation of grinding and mixing machines, the handling and preparation of materials, and the application of products—

- Industrial and Power Alcohol*, by R. C. Farnay.  
*Filtration*, by T. Roland Wollaston.  
*Industrial Electric Heating*, by J. W. Beauchamp.  
*Mechanical Handling of Goods*, by C. H. Woodfield.  
*Belts for Power Transmission*, by W. G. Dunkley.  
*D.C. Industrial Motor Control*, by A. T. Dover.  
*D.C. Dynam and Motor Faults*, by R. M. Archer.  
*Lubrication and Lubricants*, by J. H. Hyde.  
*House Decorations and Repairs*, by Wm. Prebble.

Many other volumes are in preparation for the series of Technical Primers, full particulars of which can be obtained from the publishers at Pitman House, Parker Street, Kingsway, W.C.2.

# INDEX

The references are to **PARAGRAPHS**: where more than one reference is given, the number of the principal paragraph is in heavy type.

- ACETONE, 80
- Alcohol, 74, 80
- Alumina, 62
- Aluminum powder, 69, 75, 81
  - silicate, 45
- Amyl acetate, 80
  - alcohol, 80
- Antimony oxide, 41A
- Anthracene oil, 73
- Asbestos, 47
- Asphalt, 71
- BARIUM** sulphate, 39, **43, 44**
- Barytes, 28, 35, 36, 42, **43**, 58, 62
- Basic lead carbonate, 28, 32, 35, **40**
  - sulphate, 38, **41**
- Benzol, 73, 80
- Bituminous coatings, 4, 6, **71**
- Black pigments, 50
- Black varnish, 71, 72, 73
- Blanc fixe, **44**, 62
- Bleeding, 62
- Blooming, 24
- Blue pigments, 58, 59
- Brunswick black, 72
  - green, 32, 42, **60**
- CALCIUM** rosinate, 63
- Camphor, 80
- Carbon black, 50
- Casein, 81
- Catalysis, 11
- Celluloid, 5, **80**
- Cellulose acetate, 82
- Chalk, 48
- China clay, 36, 42, **45, 62**
- Chinese red, 56
  - wood oil, **17, 24, 25, 31**
- Chrome oxide green, 61
- Couch paints, 5, **69**
- Coal tar, 73
- Cobalt, 11
- Collodion, 80
- Copal, 15
  - melting of, 17
- Cotton seed oil, 64
- Covering capacity, 31, 33, 42
- DAMAR**, 63
  - Distempers, 39, 44, 48, **83**
  - washable, 85
- Dope, 81, 83
- Driers, **11, 22, 63, 67, 68**
- Drop black, 50
- Dyes, 62
- EMERALD** green, 62
- Enamels, **30, 37, 70**
- Eosin, 62
- Ether, 80
- Ethyl acetate, 80
- FACTORIES**, 3
  - varnish, **16**
- Fillers, 42
- Fireproof paints, 47
- Floors, 2
- French polish, 5, **78**
- Fusel oil, 80
- Gas oil, 70
- Gelatine, 83

- Gilsomite, 72  
 Glue, 83  
 Gold leaf, 67  
 — size, 66, 67  
 Graphite, 51  
 Green earth, 62  
 — lake, 62  
 — oil, 73  
 Grinding, 34  
 Gum running, 17  
 Gypsum, 49  
  
**HARDENED ROSIN, 63**  
  
**INDIAN RED, 52**  
 Interiors, 1  
 Iron oxide, black, 32, 52  
 — brown, 32, 52  
 — red, 32, 42, 52  
 — protection, 4, 71  
  
**KAOLIN, 45**  
 Kauri, 63  
  
**LABORATORY, 10**  
 Lacquer, 75, 81  
 Lake colours, 62  
 Lamp black, 50  
 Lead, 11  
 — chromate, 32, 54, 56, 60  
 — manganese rosinate, 11, 63, 68  
 — sulphate, basic, 38, 41  
 — sulphide, 39, 40  
 — (white), 28, 32, 35, 40  
 Leaded zinc, 38  
 Lemon chrome, 56  
 Lime, 3  
 Linoleum, 2  
 Linoxyn, 27, 42, 64  
 Linseed oil, 7, 27, 29, 59, 85  
 — boiled, 8  
 — breaking, 7  
 — constants, 7  
 — film, 31  
 — for varnishes, 18  
 — foots, 7  
 — rate of drying, 11, 50  
 Linseed oil, refined, 7  
 — substitutes, 70  
 — tanking, 7  
 Liquid rosin, 64  
 Lithol red, 32  
 Lithopone, 32, 39, 78  
  
**MAGENTA, 62**  
 Magnesium silicate, 47  
 Manganese, 11  
 — rosinate, 63  
 Manilla, soft, 63, 77  
 Maroon, 62  
 Metallic powders, 69, 75, 81  
 Methylated spirit, 73, 80  
 Mills, 34  
 Mineral oil, 64, 70  
  
**NAPHTHA, 63, 73**  
 Nitro-cellulose, 80  
  
**OCHRE, 54**  
 Oil absorption, 33, 36  
 "Oiling up," 19  
 Oleo resin, 13, 64  
 Opacity, 36, 42  
 Orange chrome, 56  
 — lead, 55, 62  
 Organic pigments, 62  
  
**PAINT, 26, 70**  
 — manufacture of, 34  
 — specifications, 32, 33  
 Paris white, 48  
 Paste "paint," 26, 45  
 Pigments, general properties, 33, 35  
 Pitch, coal tar, 71, 73  
 — petroleum, 72  
 Plaster of Paris, 49  
 Polymerization, 9, 49, 25  
 Porous surfaces, 2, 27  
 Prussian blue, 58, 60  
  
**RAPE oil, 64**  
 Red lead, 55, 62  
 Refractive index, 42  
 Rosin, 12, 13, 24, 63, 70, 79  
 — oil, 64, 70

- SALT water, 6  
 Sandarac, 72  
 "Set" pot, 21  
 Shellac, 2, 5, **74**  
 Sienna, 54  
 Sihca, 46  
 Stand oil, **9**, 30  
 Stoving, 5  
 Submerged surfaces, 6  
 Sulphuretted hydrogen, 10
- TEREBINE, 11, 67  
 Terra alba, 35, **49**  
 Thinning down, 20  
 Timonox, 41A  
 Titan white, 41A  
 Tung oil, 12, 17, 24, **25**, 31  
 Turkey red, 52  
 Turpentine, **13**, 28, 63
- ULTRAMARINE, 37, 49, **59**, 83  
 Umber, 32, **53**
- VARNISH, Chinese wood oil, 24  
 —, copal, 12, **15**, 30, 66  
 —, copal, manufacture of, 17  
 — — fumes, 17, 64, 70  
 — — manufacture, 16  
 — —, short-oil, 66  
 — — tanking, 23  
 Vegetable black, 51  
 Venetian red, 52  
 Vermilionette, 62  
 Volume basis, 32
- WALLS, 1  
 Water gas tar, 73  
 — — paints, 82  
 White lead, 28, 32, 35, **40**  
 — — spirit, **14**, 28, 63, 70  
 Whitewash, 3, 83  
 Whiting, 35, 42, **48**, 83
- YELLOW pigments, 54, **56**, 57
- ZINC chrome, 57  
 — — leaded, 38  
 — — oxide, 28, 30, 32, 35, **37**  
 — — sulphide, 39

# GRINDING AND MIXING PLANT

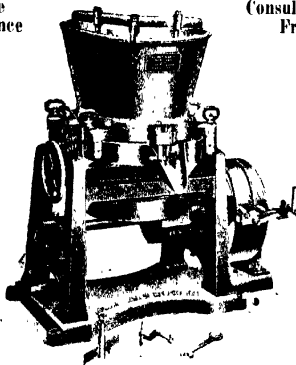
for Paints, Enamels, Dry  
Colours & Compositions

HIGHEST GRADE MACHINERY

Complete Installations Undertaken

Wide  
Experience

Consultations  
Free



The Patent "UNIVERSAL" Cone Mill

**FOLLOWS & BATÉ, Ltd,**

*Paint Works Engineers*

**GORTON, MANCHESTER**

*By mentioning this book when replying, you will oblige  
Advertiser, Author, and Publishers*



Telephone No.—“Avenue 809”      Cables—“Ruddier Ldn.”  
Telegraphic Address—“Ruddier Ald Ldn.”

---

ESTABLISHED 1861

---

# Zach Cartwright

LIMITED

62 Crutched Friars  
London, E.C.3

---

SPECIALISTS IN

## *Colour & Paint Makers' Materials*

*Dry Colours only*

*Crude & Levigated*

---

**Q** Red and Yellow, Brown and Purple,  
and Black Oxides of Iron, Zinc Oxides,  
Lithopone, Barytes, Mineral Whites, Silica,  
French Chalk, Lump and Powdered Pumice  
Stone, Manganese, Umbers, Vandyke  
Brown, Blacks, Drop Carbon and Mineral,  
Lump and Powdered Rottenstone, Neuberger  
Earth, Gums, Chemicals, etc., etc.

*By mentioning this book when replying, you will oblige  
Advertiser, Author, and Publishers*

"Pitman's Primers are all notable for the amount of information expressed clearly in a small space." —*The Manchester Guardian*.

---

# *Pitman's Technical Primers*

---

*Edited by* R. E. NEALE, B.Sc. (Hons.)  
A.S.G.I., A.M.I.E.E.



IN each book of the series the fundamental principles of some sub-division of technology are treated in a practical manner, providing the student with a handy survey of the particular branch of technology with which he is concerned. They should prove invaluable to the busy practical man who has not the time for more elaborate treatises.

*Each in foolscap 8vo, about 120 pp.  
illustrated, 2/6 net*

---

SIR ISAAC PITMAN AND SONS, LTD.  
PARKER STREET, KINGSWAY, LONDON, W.C.2

# *Pitman's Technical Primers*

*Each 2/6 net*

---

- The Steam Locomotive.** By E. L. Ahrons, M.I.Mech.E.,  
M.I.Loco.E.
- Belts for Power Transmission.** By W. G. Dunkley, B.Sc.  
(Hons.).
- Water-Power Engineering.** By F. F. Fergusson,  
A.M.Inst.C.E.
- Photographic Technique.** By L. J. Hubbert, F.R.P.S.
- Hydro-Electric Development.** By J. W. Mears, F.R.A.S.,  
M.Inst.C.E., M.I.E.E.
- The Electrification of Railways.** By H. F. Trewman,  
M.A.
- Continuous Current Armature Winding.** By F. M. Denton,  
A.C.G.I., A.M.I.E.E.
- Municipal Engineering.** By H. Percy Boulnois,  
M.Inst.C.E., F.R.San.Inst.
- Foundrywork.** By Ben Shaw and James Edgar.
- Patternmaking.** By Ben Shaw and James Edgar.
- The Electric Furnace.** By Frank J. Moffett, B.A.,  
M.I.E.E., M.Cons.E.
- Small Single-Phase Transformers.** By E. T. Painton,  
B.Sc. (Hons.), A.M.I.E.E.
- Pneumatic Conveying.** By E. G. Phillips, M.I.E.E.,  
A.M.I.Mech.E.
- Boiler Inspection and Maintenance.** By R. Clayton.
- Electricity in Steel Works.** By W. McFarlane, B.Sc.
- Modern Central Stations.** By C. W. Marshall, B.Sc.
- Steam Locomotive Construction and Maintenance.** By  
E. L. Ahrons, M.I.Mech.E., M.I.Loco.E.
- High Tension Switchgear.** By H. E. Poole, B.Sc. (Hons.),  
A.C.G.I., A.M.I.E.E.
- High Tension Switchboards.** By the same Author.
- Power Factor Correction.** By A. E. Clayton, B.Sc.,  
A.K.C., A.M.I.E.E.
- Tool and Machine Setting.** By P. Gates.
- Tidal Power.** By A. Struben, O.B.E., A.M.I.C.E.

# *Pitman's Technical Primers*

Each 2/6 net

---

- Sewers and Sewerage.** By H. Gilbert Whyatt, M Inst C.E.,  
M R San Inst.
- Elements of Illuminating Engineering.** By A. P. Trotter,  
M I E E
- Coal-Cutting Machinery.** By G. E. F. Lager, M Inst Min E.
- Grinding Machines and Their Use.** By T. R. Shaw,  
M.I.Mech.E.
- Electro-Deposition of Copper.** By C. W. Denny, A M I E.E.
- Directive Wireless Telegraphy.** By L. H. Walter, M.A.,  
A M I E E.
- Testing of Continuous-Current Machines.** By C. F. Smith,  
D.Sc., M I E E, A M I C E.
- The Electrical Transmission of Energy.** By W. M.  
Thornton, D.Sc.
- Steam Engine Valves and Valve Gears.** By E. L. Ahrens,  
M.I.Mech.E.
- Mechanical Handling of Goods.** By C. H. Woodfield,  
M.I.Mech.E.
- Industrial and Power Alcohol.** By R. C. Farmer, O.B.E.,  
D.Sc., Ph.D., F.I.C.
- Radioactivity and Radioactive Substances.** By J. Chad-  
wick, Ph.D., M.Sc. With a Foreword by Sir Ernest  
Rutherford, F.R.S.
- House Decorations and Repairs.** By W. Prebble.
- Electric Power Systems.** By Capt. W. T. Taylor,  
M.Inst.C.E., M.I.Mech.E.
- High Voltage Power Transformers.** By the same Author.
- The Manufacture and Uses of Explosives.** By R. C.  
Farmer, C.B.E., D.Sc., Ph.D., F.I.C.
- Cotton Spinning Machinery and Its Uses.** By W. Scott  
Taggart.
- Town Gas Manufacture.** By Capt. Ralph Staley, M.C.,  
R.E.
- Electric Cables.** By F. W. Main A.M.I.E.E.
- Capstan and Automatic Lathes.** By Philip Gates.

# *Pitman's Technical Primers*

*Each 2/6 net*

---

**Kinematograph Studio Technique.** By L. C. MacBean  
**Industrial Nitrogen.** By P. H. S. Kempton, B.Sc. (Hons.),  
A.R.C.Sc.

**The Testing of Transformers and Alternating-Current  
Machines.** By Charles F. Smith, D.Sc., M.I.E.E.

**Continuous Wave Wireless Telegraphy.** By B. E. G.  
Mittell, A.M.I.E.E.

**Switching and Switchgear.** By H. E. Poole, B.Sc. (Hons.)

**Industrial Motor Control.** By A. T. Dover, M.I.E.E.

**Petrol Cars and Lorries.** By F. Heap.

**Oils, Pigments, Paints and Varnishes.** By Rupert H.  
Truelove

**Filtration.** By T. R. Wollaston, M.I. Mech.E.

**Metallurgy of Iron and Steel.** Based on Papers by Sir  
Robert Hadfield, Bt.

**Electric Traction Controls.** By A. T. Dover, M.I.E.E.

**Industrial Application of X-Rays.** By P. H. S. Kempton,  
B.Sc. (Hons.)

**Abrasive Materials.** By A. B. Searle

**Sparking Plugs.** By A. P. Young and H. Warren.

**Electricity in Agriculture.** By A. H. Allen, M.I.E.E.

**Railway Signalling : Automatic.** By F. Raynar Wilson.

**Railway Signalling : Mechanical.** By F. Raynar Wilson.

**Lubricants and Lubrication.** By J. H. Hyde, *of the  
National Physical Laboratory.*

**Special Steels.** Based on Notes by Sir Robert Hadfield,  
Bart., compiled by J. H. Burnham, B.Sc. (Double  
Vol., price 5s. net)

**The Diesel Engine.** By A. Orton

**Drop Forging and Drop Stamping.** By H. Hayes.

*Descriptive Lists post free on application*

---

**SIR ISAAC PITMAN AND SONS, LTD.**  
**PARKER STREET, KINGSWAY, LONDON, W.C.2**

## DECORATION BY TRANSFERS

Perfectly executed decorations of every description required by Decorators. Experience unnecessary. A high class **Door Panel Decoration** would take only half-hour to one hour for the most elaborate job. Its cost might be 2s. to 10s. You would get, probably, the same number of pounds for it. Can be applied to **Paint Work, Varnish, Paper, Glass, Metal**, etc. Specially prepared Transfers supplied for application to **Distempers, Whitewash** or unprepared **Wood, Leather** or **Fabrics**.

(*Illus. List 2d. Sample 1 6 (state class required)*)

**AXON & HARRISON, JERSEY, C.I.**

## HOUSE DECORATIONS —AND REPAIRS—

By WM. PREBBLE

Describes in the simplest and most practical manner the various methods employed in household decorations and repairs, such as

**DISTEMPERING      PAPERING      PAINTING**  
**PLASTERING      RENEWING SASH LINES**  
**SIMPLE PLUMBING JOBS      REPAIRING LOCKS**  
**GLAZING      STAINING AND VARNISHING**  
**ROOFING REPAIRS, etc., etc.**

"The methods recommended are very simple and practical, and a number of clearly-drawn diagrams serve to elucidate the more difficult operations." *The Daily Mail*

*Price 2s. 6d. net*  
*OF ALL BOOKSELLERS.*

SIR ISAAC PITMAN & SONS, LTD., PARKER ST., KING WAY, W.C. 2

*By mentioning this book when replying, you will oblige  
Advertiser, Author, and Publishers*

A HANDY REFERENCE BOOK

THE  
CERAMIC  
INDUSTRIES  
POCKET BOOK

BY

ALFRED B. SEARLE

*Author of "Clays and Clay Products," etc.*

This little volume is a compilation of data which has been found so useful to a number of people engaged in the clay-working, glass and allied industries that its publication in a convenient form appeared to be desirable.

It is not intended to replace text-books, but to supplement them and to present in a compact and handy manner information which is almost constantly required by those for whom the book has been compiled.

Price **8/6** net.

*of Booksellers*

SIR ISAAC PITMAN AND SONS, LIMITED  
PARKER STREET, KINGSWAY, LONDON, W.C.2

*FROM "THE BUILDER" SERIES*

## **Carpentry and Joinery**

Fifth Edition, Revised

A Text-book for Architects, Engineers, Surveyors, Craftsmen, and Students

By BANISTER F. FLETCHER, F.R.I.B.A., F.S.I., etc.; and H. PHILLIPS FLETCHER, F.R.I.B.A., F.S.I., etc

CONTENTS. Woods. Timber. Tools. Joints. Roofs. Bridges. Shoring and Strutting. Centres. Scaffolding, Staging, and Gables. Pillars, Beams, and Girders. Floors. Floor Coverings. Framed Partitions and Frame Houses. Joints used in Joinery. Hinging. Mouldings. Doors. Windows. Framing. Skylights and Lanterns. Staircases. Shaped Work. Bevels. Rods. Workshop Practice. Artistic Craftsmanship. Index.

In crown 8vo, with 500 illustrations. **10s. 6d. net.**

## **Architectural Hygiene; or, Sanitary Science as Applied to Buildings**

Fifth Edition, Revised

A Text-book for Architects, Surveyors, Engineers, Medical Officers of Health, Sanitary Inspectors, etc

By the same Authors.

CONTENTS. Sanitary Legislation. Site and Foundation. Plan in Regard to Health and Convenience. Sanitary Construction. House Drainage. Drain. Ventilation, Siphonage, and Trap. Sanitary Fittings. Collection and Disposal of Refuse and Sewage. Drainage Plans. Water Supply and Pollution. Water-Supply. Fittings. Ventilation. Heating. Lighting. Sanitary Inspection. Surveys and Reports. Sanitation of a Country House. Index.

In crown 8vo, with 306 illustrations. **10s. 6d. net.**

*OF ALL BOOKSELLERS*

---

**GIR ISAAC PITMAN & SONS, LTD.,**  
PARKER STREET, KINGSWAY, LONDON, W.C.2



# PITMAN'S BOOKS

Each 3s. net.

---

**PAINTS AND VARNISHES.** By A. S. JENNINGS, F.I.B.D.

**FURNITURE.** By H. E. BINSTED.

**WALLPAPER.** By G. WHITELEY WARD.

**TIMBER.** By W. BULLOCK.

**STONES AND QUARRIES.** By J. ALLEN HOWE, O.B.E., B.Sc., M.I.M.M.

**CONCRETE AND REINFORCED CONCRETE.** By W. NOBLE TWELVETREES, M.I.Mech.E.

**LEAD (including Lead Pigments).** By J. A. SMYTHE, Ph.D., D.Sc.

**ZINC AND ITS ALLOYS.** By T. E. LONES, M.A., LL.D., B.Sc.

**OIL FOR POWER PURPOSES.** By SYDNEY NORTH.

**OILS: Animal, Vegetable, Essential, and Mineral.** By C. AINSWORTH MITCHELL, M.A., F.I.C.

**GUMS AND RESINS.** By ERNEST J. PARRY, B.Sc., F.I.C., F.C.S.

**COAL TAR.** By A. R. WARNES, F.C.S., A.I.Mech.E.

---

*Complete List post free on application.*

**SIR ISAAC PITMAN & SONS, LTD.,**  
**Parker St., Kingsway, London, W.C.2**

• Telephone No.  
Hop. 3990.

Telegraphic Address.  
"Youngbar, Rothlow,  
London."



**Younghusband Barnes & Co.**  
**Oil Boilers and**  
**Refiners.**

**Lower King & Queen Wharf,**  
**Rotherhithe, London, S.E.16.**

**Refined Linseed Oil**

**Boiled Linseed Oil**

**Double Boiled Linseed Oil**

**"Crystal" Pale Boiled Linseed Oil**

**Thickened Linseed Oil**

**Special Varnish Linseed Oil**

**Enamel Oils** Guaranteed not to "break."

**Stand Oils, all Grades**

**Refined Rapeseed Oil** (or to Specification)

**Blown Rapeseed Oil**

**Sanctuary Colza Oil**

**Linoleates & Resinates of Lead,**

• **Manganese & Cobalt**

*By mentioning this book when replying, you will oblige  
Advertiser, Author, and Publishers*

**TAYLOR BROS. & COX,**

**LIMITED**

**5 MARK LANE, LONDON, E.C.3**

**SOLICIT ENQUIRIES**

from

**KEEN BUYERS**

looking for

**BEST VALUES & SERVICE**

---

Specialists in

**RAW MATERIALS,**

**MINERALS, COLOURS**

**AND PIGMENTS**

for the

**PAINT, COLOUR, VARNISH and**

**KINDRED INDUSTRIES**

'Phone: Avenue 4743 & 4744. Cable: "Lithopone" London.

---

**STOCKS HELD**

*By mentioning this book when replying, you will oblige  
Advertiser, Author, and Publishers*

AN ABRIDGED LIST OF  
**TECHNICAL BOOKS**

PUBLISHED BY

**Sir Isaac Pitman & Sons, Ltd.**  
 PARKER STREET, KINGSWAY  
 LONDON, W.C.2

The prices given apply only to Great Britain

A complete Catalogue giving full details of the following  
 books will be sent post free on application

ALL PRICES ARE NET

• **THE ARTISTIC CRAFTS SERIES**

BOOKBINDING AND THE CARE OF BOOKS. By Douglas Cockerell. Fourth Edition . . . . .	s. d.
DRESS DESIGN By Talbot Hughes . . . . .	19 6
EMBROIDERY AND TAPESTRY WEAVING. By Mrs. A. H. Christie Fourth Edition . . . . .	12 6
HAND-LOOM WEAVING By Luther Hooper. . . . .	10 6
HERALDRY. By Sir W. H. St. John Hope, Litt.D., D.C.L. . . . .	10 6
SILVERWORK AND JEWELLERY By H. Wilson Second Edition . . . . .	12 6
STAINED GLASS WORK. By C. W. Whall . . . . .	8 6
WOOD-BLOCK PRINTING. By F. Morley Fletcher . . . . .	10 6
WOODCARVING DESIGN AND WORKMANSHIP. By George Jack. Second Edition . . . . .	8 6
WRITING AND ILLUMINATING AND LETTFRING. By Edward Johnston. Fifteenth Edition . . . . .	8 6

• **APT AND CRAFT WORK, Etc.**

BLOCK-CUTTING AND PRINT-MAKING BY HAND. By Margaret Dobson, A.R.E. . . . .	12 <sup>6</sup> 6
CABINET-MAKING, THE ART AND CRAFT OF. By D. DeWing . . . . .	7 6
CELLULOSE LACQUERS. By S. Smith, O.B.E., Ph.D. . . . .	7 6
HANDRAILING FOR GEOMETRICAL STAIRCASES By W. A. Scott . . . . .	2 6

## 2 PITMAN'S TECHNICAL BOOKS

	s.	d.
LACQUER WORK. By G. Koizumi . . . . .	15	0
LEATHER CRAFT, ARTISTIC. By Herbert Turner . . . . .	5	0
LEATHER WORK. STAMPED, MOULDED, CUT, CUIR-BOUILLI, SEWN, ETC. By Charles G. Leland. Third Edition . . . . .	5	0
LETTERING, DECORATIVE WRITING AND ARRANGEMENT OF. By Prof A. Erdmann and A. A. Braun. Second Edition . . . . .	10	6
LETTERING AND DESIGN, EXAMPLES OF. By J. Littlejohns, R.B.A. . . . .	4	0
LETTERING, PLAIN AND ORNAMENTAL. By Edwin G. Fooks . . . . .	3	6
MANUAL INSTRUCTION. WOODWORK. By S. Barter . . . . .	7	6
MANUSCRIPT AND INSCRIPTION LETTERS. By Edward Johnston. Fifth Impression . . . . .	7	6
MANUSCRIPT WRITING AND LETTERING. By An Educational Expert . . . . .	6	0
METAL WORK. By Charles G. Leland. Second Edition . . . . .	5	0
NEEDLEWORK IN RELIGION. By Mrs. Antrobus and Miss Preece . . . . .	21	0
ORNAMENTAL HOMECRAFTS. By Idalia B. Littlejohns . . . . .	10	6
PLYWOOD AND GLUE, MANUFACTURE AND USE OF. By B. C. Boulton, B.Sc. . . . .	7	6
POTTERY, HANDCRAFT. By H. and D. Wren . . . . .	12	6
STAINED GLASS, THE ART AND CRAFT OF. By E. W. Twining . . . . .	42	0
STENCIL-CRAFT. By Henry Cadness, F.S.A.M. . . . .	10	6
WEAVING FOR BEGINNERS. By Luther Hooper . . . . .	5	0
WEAVING WITH SMALL APPLIANCES—		
THE WEAVING BOARD. By Luther Hooper . . . . .	7	6
TABLE LOOM WEAVING. By Luther Hooper . . . . .	7	6
TABLET WEAVING. By Luther Hooper . . . . .	7	6
WOOD-CARVING. By Charles G. Leland. Fifth Edition . . . . .	7	6
WOODCARVING, HANDICRAFT OF. By James Jackson . . . . .	4	0
<b>TEXTILE MANUFACTURE, Etc.</b>		
ARTIFICIAL SILK. By Dr O. Faust. Translated from the German by Ernest Fyleman, B.Sc., Ph.D., F.I.C. . . . .	10	6
ARTIFICIAL SILK. By Joseph Foltzer. Translated into English by T. Woodhouse. Fourth Edition . . . . .	21	6

# PITMAN'S TECHNICAL BOOKS 3

	s.	d.
ARTIFICIAL SILK. By Dr. V. Hottenroth. Translated from the German by Dr. E. Fyleman, B.Sc.	30	0
ARTIFICIAL SILK OR RAYON, ITS MANUFACTURE AND USES By T. Woodhouse, F.T.I.	7	6
BLEACHING, DYEING, PRINTING, AND FINISHING FOR THE MANCHESTER TRADE By J. W. McMyn, F.C.S., and J. W. Bardsley	6	0
COLOUR IN WOVEN DESIGN. By Roberts Beaumont, M.Sc., M.I. Mech.E. Second Edition, Revised and Enlarged	21	0
COTTON SPINNER'S POCKET BOOK, THE By James F. Innes	3	6
COTTON SPINNING COURSE, A FIRST YEAR. By H. A. J. Duncan, A.T.I.	5	0
DRESS, BLOUSE, AND COSTUME CLOTHS. Design and Fabric Manufacture. By Roberts Beaumont, M.Sc., M.I. Mech.E., and Walter G. Hill	42	0
FLAX CULTURE AND PREPARATION. By F. Bradbury Second Edition	10	6
FURS AND FURRIERY. By Cyril J. Rosenberg	3	0
HOSIERY MANUFACTURE. By W. Davis, M.A.	7	6
PATTERN CONSTRUCTION, THE SCIENCE OF. For Garment Makers. By B. W. Poole	45	0
SPINNING, WEAVING, AND FINISHING OF FLAX AND JUTE By T. Woodhouse, F.T.I., and P. Kilgour	10	6
TEXTILE CALCULATIONS. By J. H. Whitwam, B.Sc. (Lond.).	25	0
TEXTILE EDUCATOR, PITMAN'S. Edited by L. J. Mills, <i>Fellow of the Textile Institute</i> . In three volumes	63	9
TEXTILES, INTRODUCTION TO. By A. F. Lewis, A.M.C.T.	3	6
TOWELS AND TOWELLING, THE DESIGN AND MANUFACTURE OF. By T. Woodhouse, F.T.I., and A. BRAND	12	6
UNION TEXTILE FABRICATION. By Roberts Beaumont, M.Sc., M.I. Mech.E.	21	0
WEAVING AND MANUFACTURING, HANDBOOK OF. By H. Greenwood	5	0
WOOLLEN YARN PRODUCTION. By T. Lawson	3	6
WOOL SUBSTITUTES. By Roberts Beaumont	10	6

# 4 PITMAN'S TECHNICAL BOOKS

	s	d.
YARNS AND FABRICS, THE TESTING OF. By H. P. Curtis . . . . .	5	0

## DRAUGHTSMANSHIP

BLUE PRINTING AND MODERN PLAN COPYING. By B. J. Hall, M.I. Mech. E. . . . .	6	0
BLUE PRINT READING. By J. Brahdv, B.Sc., C.E. . . . .	10	6
DRAWING AND DESIGNING. By Charles G. Leland, M.A. Fourth Edition . . . . .	3	6
DRAWING OFFICE PRACTICE. By H. Pilkington Waid, M.Sc., A.M. Inst. C.E. . . . .	7	6
ENGINEER DRAUGHTSMEN'S WORK. By A. Practical Draughtsman . . . . .	2	6
ENGINEERING HAND SKETCHING AND SCALE DRAWING. By Thos. Jackson, M.I. Mech. E., and Percy Bentley, A.M.I. Mech. E. . . . .	3	0
ENGINEERING WORKSHOP DRAWING. By A. C. Parkinson, A.C.P. (Hons.), M. Coll. H. (Hons.) . . . .	4	0
MACHINE DESIGN, EXAMPLES IN. By G. W. Bird, B.Sc. . . . .	6	0
MACHINE DRAWING, A PREPARATORY COURSE TO BY P. W. Scott . . . . .	2	0
MANUAL INSTRUCTION: DRAWING. By S. Barter . . . . .	4	0
PLAN COPYING IN BLACK LINES. By B. J. Hall, M.I. Mech. E. . . . .	2	6

## PHYSICS, CHEMISTRY, Etc.

BOTANY, TEST PAPERS IN. By E. Drabble, D.Sc. . . . .	2	0
CHEMICAL ENGINEERING, AN INTRODUCTION TO By A. F. Allen, B.Sc. (Hons.), F.C.S., LL.B. . . . .	10	6
CHEMISTRY, A FIRST BOOK OF. By A. Coulthard, B.Sc. (Hons.), Ph.D., F.I.C. . . . .	3	0
CHEMISTRY, TEST PAPERS IN. By E. J. Holmyard, M.A. . . . .	2	0
With Points Essential to Answers . . . . .	3	0
CHEMISTRY, TEST PAPER IN, HIGHER. By the same Author. 1. Inorganic. 2. Organic . . . . .	3	0
DISPENSING FOR PHARMACEUTICAL STUDENTS. By F. J. Dyer and J. W. Cooper . . . . .	7	6
ELECTRICITY AND MAGNETISM, FIRST BOOK OF. By W. Perren Maycock, M.I.E.E. Fourth Edition . . . . .	6	0
MAGNETISM AND ELECTRICITY, HIGHER TEST PAPERS IN. By P. J. Lancelot Smith, M.A. . . . .	3	0
ENGINEERING PRINCIPLES, ELEMENTARY. By G. E. Hall, B.Sc. . . . .	2	6

# PITMAN'S TECHNICAL BOOKS 5

	s. d.
ENGINEERING SCIENCE, A PRIMER OF. By Ewart S. Andrews, B.Sc. (Eng.). Complete Edition . . .	3 6
Part. I. FIRST STEPS IN APPLIED MECHANICS . . .	2 6
PHYSICAL SCIENCE, PRIMARY. By W. R. Bower, B.Sc. . .	5 0
PHYSICS, EXPERIMENTAL. By A. Cowling. With arithmetical answers to the problems. . .	1 9
PHYSICS, TEST PAPERS IN. By P. J. Lancelot-Smith, M.A. . . . .	2 0
Points Essential to Answers, 4s. In one book . . .	5 6
SCIENCE OF THE SOIL, THE. By Charles Watrell . . .	3 6
VOLUMETRIC ANALYSIS. By J. B. Coppock, B.Sc. (Lond.), F.I.C., F.C.S. Second Edition . . .	3 6
VOLUMETRIC WORK, A COURSE OF. By E. Clark, B.Sc. . . . .	4 6

## METALLURGY AND METAL WORK

AIRCRAFT AND AUTOMOBILE MATERIALS—FERROUS. By A. W. Judge, Wh.Sc., A.R.C.S. . . . .	25 0
AIRCRAFT AND AUTOMOBILE MATERIALS—NON-FERROUS AND ORGANIC. By A. W. Judge, Wh.Sc., A.R.C.S. . . . .	25 0
BALL AND ROLLER BEARINGS, HANDBOOK OF. By A. W. Macaulay, A.M.I.Mech.E. . . . .	7 6
ENGINEERING WORKSHOP EXERCISES. By Ernest Pull, A.M.I.Mech.E., M.I.Mar.E. Second Edition, Revised . . . . .	3 6
FILES AND FILING. By Ch. Fremont, translated into English under the supervision of George Taylor . . . . .	21 0
FITTING, THE PRINCIPLES OF. By J. Horner, A.M.I.M.E. Fifth Edition, Revised and Enlarged . . . . .	7 6
IRONFOUNDING, PRACTICAL. By J. Horner, A.M.I.M.E. Fourth Edition . . . . .	10 0
METAL TURNING. By J. Horner, A.M.I.M.E. Fourth Edition, Revised and Enlarged . . . . .	6 0
METAL WORK, PRACTICAL SHEET AND PLATE. By E. A. Atkins, A.M.I.M.E. Third Edition, Revised and Enlarged. . . . .	7 6
METALLURGY OF CAST IRON. By J. E. Hurst . . . . .	15 0
PATTERN MAKING, THE PRINCIPLES OF. By J. Horner, A.M.I.M.E. Fifth Edition . . . . .	4 0
PIPE AND TUBE BENDING AND JOINTING. By S. P. Marks, M.S.I.A. . . . .	6 0



## 6 PITMAN'S TECHNICAL BOOKS

	<i>s</i>	<i>d</i>
PYROMETERS. By F. Griffiths, D.Sc. . . . .	7	6
STEEL WORKS ANALYSIS. By J. O. Arnold, F.R.S., and F. Ibbotson. Fourth Edition, thoroughly Revised. . . . .	12	6
TURRET LATHE TOOLS, HOW TO LAY OUT Second Edition . . . . .	6	0
WELDING, ELECTRIC. By L. B. Wilson. . . . .	5	0
WELDING, ELECTRIC ARC AND OXY-ACETYLENE. By E. A. Atkins, A.M.I.M.E. . . . .	7	6
WORKSHOP GAUGES AND MEASURING APPLIANCES. By L. Burn, A.M.I. Mech E., A.M.I.E.E. . . . .	5	0
WORKSHOP PRACTICE Edited by E. A. Atkins, M.I. Mech E., M.I.W.E. In eight Volumes. Each . . . . .	6	0
I. TOOLS, CALCULATIONS, DRAWING, METALS.		
II. PATTERN-MAKING AND FOUNDRY WORK.		
III. STEELS, LATHES, SHAPING, PLANING.		
IV. GRINDING, SLOTTING, MILLING, JIGS AND TOOLS, TURRETS.		
V. DROP FORGING, DIE MAKING, PRESS WORKING AND STAMPING, PRACTICAL BLACKSMITHING		
VI. SHEET AND PLATE METAL WORKING, WIRE AND TUBE MANUFACTURE, GEAR- CUTTING.		
VII. FITTING AND ENGINE ERECTION. Part I.		
VIII. FITTING AND ENGINE ERECTION. Part II.		

### MINERALOGY AND MINING

BLASTING WITH HIGH EXPLOSIVES. By W. Gerard Boulton . . . . .	5	0
COAL CARBONIZATION. By John Roberts, D.I.C., M.I. Min.E., F.G.S. . . . .	25	0
COLLIERY ELECTRICAL ENGINEERING. By G. M. Harvey . . . . .	15	0
COMPRESSED AIR POWER. By A. W. Daw and Z. W. Daw . . . . .	21	0
ELECTRICAL ENGINEERING FOR MINING STUDENTS. By G. M. Harvey, M.Sc., B.Eng., A.M.I.E.E. . . . .	3	0
ELECTRICITY APPLIED TO MINING By H. Cotton, M.B.E., M.Sc., A.M.I.E.E. . . . .	35	0

	s.	d.
ELECTRIC MINING MACHINERY. By Sydney F. Walker, M.I.E.E., M.I.M.E., A.M.I.C.E., A.Amer.I.E.E.	15	0
GOLD PLACERS, THE DREDGING OF By J. E. Hodgson, F.R.G.S.	5	0
LOW TEMPERATURE DISTILLATION By S. North and J. B. Garbe	15	0
MINERALOGY. By F. H. Hatch, Ph.D., F.G.S., M.I.C.E., M.I.M.M. Fifth Edition, Revised.	6	0
MINING CERTIFICATE SERIES, PITMAN'S Edited by John Roberts, D.I.C., M.I.Min.E., F.G.S., Editor of <i>The Mining Educator</i> --		
MINING LAW AND MINE MANAGEMENT. By Alexander Watson, A.R.S.M.	8	6
MINE VENTILATION AND LIGHTING. By C. D. Mottram, B.Sc.	8	6
COLLIERY EXPLOSIONS AND RECOVERY WORK. By J. W. Whitaker, Ph.D. (Eng.), B.Sc., F.I.C., M.I.Min.E.	8	6
ARITHMETIC AND SURVEYING. By R. M. Evans, B.Sc., F.G.S., M.I.Min.E.	8	6
MINING MACHINERY. By T. Bryson, A.R.T.C., M.I.Min.E.	12	6
WINNING AND WORKING By Prof. Ira C. F. Statham, B.Eng., F.G.S., M.I.Min.E.	21	0
MINING EDUCATOR, THE. Edited by J. Roberts, D.I.C., M.I.Min.E., F.G.S. In two vols.	63	0
MINING SCIENCE, A JUNIOR COURSE IN. By Henry G. Bishop	2	6
TIN MINING. By C. G. Moor, M.A.	8	6

# CIVIL ENGINEERING, BUILDING, Etc.

AUEL'S MASONS' AND BUILDERS' GUIDES. In four volumes.	7	6
1. BRICKWORK, BRICK-LAYING, BONDING, DESIGNS.		
2. BRICK FOUNDATIONS, ARCHES, TILE SETTING, ESTIMATING.		
3. CONCRETE MIXING, PLACING FORMS, REINFORCED STUCCO.		
4. PLASTERING, STONE MASONRY, STEEL CONSTRUCTION, BLUE PRINTS.		

## 8 PITMAN'S TECHNICAL BOOKS

		s	d
AUDEL'S PLUMBERS' AND STEAM FITTERS' GUIDES.			
Practical Handbooks in four volumes . . . Each		7	6
1. MATHEMATICS, PHYSICS, MATERIALS, TOOLS, LEADWORK.			
2. WATER SUPPLY, DRAINAGE, ROUGH WORK, TESTS.			
3. PIPE FITTING, HEATING, VENTILATION, GAS, STEAM.			
4. SHEET METAL WORK, SMITHING, BRAZING, MOTORS.			
"THE BUILDER" SERIES—			
ARCHITECTURAL HYGIENE; OR, SANITARY SCIENCE AS APPLIED TO BUILDINGS. By Banister F. Fletcher, F.R.I.B.A., F.S.I., and H. Phillips Fletcher, F.R.I.B.A., F.S.I. Fifth Edition, Revised . . . . .		10	6
CARPENTRY AND JOINERY. By Banister F. Fletcher, F.R.I.B.A., F.S.I., etc., and H. Phillips Fletcher, F.R.I.B.A., F.S.I., etc. Fifth Edition, Revised . . . . .		10	6
QUANTITIES AND QUANTITY TAKING. By W. E. Davis Sixth Edition . . . . .		6	0
BUILDING EDUCATOR, PITMAN'S. Edited by R. Greenhalgh, A.I.Struct.E. In three vols. . . . .		63	0
FIELD MANUAL OF SURVEY METHODS AND OPERATIONS. By A. Lovat Higgins, B.Sc., A.R.C.S., A.M.I.C.E. . . . .		21	0
FIELD WORK FOR SCHOOLS. By E. H. Harrison, B.Sc., L.C.P., and C. A. Hunter . . . . .		2	0
HYDRAULICS. By E. H. Lewitt, B.Sc. (Lond.), M.I.Ae.E., A.M.I.M.E. Third Edition . . . . .		10	6
JOINERY AND CARPENTRY. Edited by Richard Greenhalgh, A.I.Struct.E. In six volumes. Each . . . . .		6	0
I. TOOLS, MACHINES, JOINTS, FIXINGS.			
II. DOORS, PANELLING, GEOMETRY, WINDOWS.			
III. TIMBER, STAIRS AND HANDRAILS, FLOORS, PARTITIONS.			
IV. ROOFS, HOUSE FITMENTS, CHURCH FITTINGS, SETTING OUT, STEEL SQUARE.			
V. TECHNICAL DRAWINGS, VENEERING, TIMBER-FRAMED BUILDINGS, CALCULATIONS, DESIGN AND ORNAMENT, SHOP FRONTS AND FITTINGS.			

	s.	d.
VI. SHIP JOINERY, TEMPORARY WORK, MECHANICS, BANK AND OFFICE FITTINGS, ADMINISTRATION OF A JOINERY BUSINESS, GLOSSARY.		
SURVEYING AND SURVEYING INSTRUMENTS. By G. A. T. Middleton, A.R.I.B.A., M.S.A. Third Edition, Revised	6	0
SURVEYING, TUTORIAL. LAND AND MINE. By Thomas Bryson	10	6
WATER MAINS, LAY-OUT OF SMALL. By H. H. Hellins, M.Inst.C.E.	7	6
WATERWORKS FOR URBAN AND RURAL DISTRICTS. By H. C. Adams, M.Inst.C.E., M.I.C.E., F.S.I.	15	0

### CONSTRUCTIONAL ENGINEERING

REINFORCED CONCRETE, DETAIL DESIGN IN. By Ewart S. Andrews, B.Sc. (Eng.)	6	0
REINFORCED CONCRETE. By W. Noble Twelvetrees, M.I.M.E., A.M.I.E.E.	21	0
REINFORCED CONCRETE MEMBERS, SIMPLIFIED METHODS OF CALCULATING. By W. Noble Twelvetrees. Second Edition, Revised and Enlarged	5	0
SPECIFICATIONS FOR BUILDING WORKS. By W. L. Evershed, F.S.I.	5	0
STRUCTURES, THE THEORY OF. By H. W. Coultas, M.Sc., A.M.I.Struc.E., A.I.Mech.E.	15	0

### MECHANICAL ENGINEERING

AUDEL'S ENGINEERS' AND MECHANICS' GUIDES. In eight volumes. Vols. 1-7	each	7	6
Vol. 8		15	0
CONDENSING PLANT. By R. J. Kaula, M.I.E.E., and I. V. Robinson, M.I.E.E.		30	0
DEFINITIONS AND FORMULAE FOR STUDENTS—APPLIED MECHANICS. By E. H. Lewitt, B.Sc., A.M.I.Mech.E.		6	
DEFINITIONS AND FORMULAE FOR STUDENTS—HEAT ENGINES. By A. Rimmer, B.Eng.		6	
DIESEL ENGINES: MARINE, LOCOMOTIVE, AND STATIONARY. By David Louis Jones, Instructor, Diesel Engine Department, U.S. Navy Submarine Department		21	0

# 10 PITMAN'S TECHNICAL BOOKS

	s.	d.
ENGINEERING EDUCATOR, PITMAN'S. Edited by W. J. Kearton, M.Eng., A.M.I.Mech.E., A.M.Inst.N.A. In three volumes . . . . .	63	0
FRICTION CLUTCHES. By R. Waring-Brown, A.M.I.A.E., F.R.S.A., M.I.P.E. . . . .	5	0
FUEL ECONOMY IN STEAM PLANTS. By A. Grounds, B.Sc., A.I.C., A.M.I.Min.E. . . . .	5	0
FULL OILS AND THEIR APPLICATIONS. By H. V. Mitchell, F.C.S. . . . .	5	0
MECHANICAL ENGINEERING DETAIL TABLES. By John P. Ross . . . . .	7	6
MECHANICAL ENGINEER'S POCKET BOOK, WHITTAKER'S. Third Edition, entirely rewritten and edited by W. E. Dommott, F.Ac.S., A.M.I.A.E. . . . .	12	6
MECHANICS' AND DRAUGHTSMEN'S POCKET BOOK. By W. E. Dommott, Wh.Ex., A.M.I.A.E. . . . .	2	6
MECHANICS FOR ENGINEERING STUDENTS. By G. W. Bird, B.Sc., A.M.I.Mech.E. . . . .	5	0
MOLLIER STEAM TABLES AND DIAGRAMS, THE. Extended to the Critical Pressure English Edition adapted and amplified from the third German Edition by H. Moss, D.Sc., A.R.C.S., D.I.C. . . . .	7	6
MOLLIER STEAM DIAGRAMS. Separately in envelope . . . . .	2	0
MOTIVE POWER ENGINEERING. For Students of Mining and Mechanical Engineering. By Henry C. Harris, B.Sc. . . . .	10	6
STEAM CONDENSING PLANT. By John Evans, M.Eng., A.M.I.Mech.E. . . . .	7	6
STEAM PLANTS, THE CARE AND MAINTENANCE OF. A Practical Manual for Steam Plant Engineers. By J. E. Braham, B.Sc., A.C.G.I. . . . .	5	0
STEAM TURBINE THEORY AND PRACTICE. By W. J. Kearton, A.M.I.M.E. Second Edition . . . . .	15	0
STRENGTH OF MATERIALS. By F. V. Warrick, Ph.D., B.Sc. (Lond.), F.R.C.Sc.I., A.M.I.Mech.E. . . . .	12	6
THEORY OF MACHINES. By Louis Toft, M.Sc.Tech., and A. T. J. Kersey, B.Sc. . . . .	12	6
THERMODYNAMICS, APPLIED. By Prof. W. Robinson, M.E., M.Inst.C.E. . . . .	18	0
TURBO-BLOWERS AND COMPRESSORS. By W. J. Kearton, A.M.I.M.E. . . . .	21	0

	s.	d.
<b>AERONAUTICS, Etc.</b>		
AEROBATICS. By Major O. Stewart, M.C., A.F.C.	5	0
AERONAUTICS, ELEMENTARY, OR, THE SCIENCE AND PRACTICE OF AERIAL MACHINES. By A. P. Thurston, D.Sc. Second Edition	8	6
AEROPLANE DESIGN AND CONSTRUCTION, ELEMENTARY PRINCIPLES OF. By A. W. Judge, A.R.C.S., Wh. Ex., A.M.I.A.E.	7	6
AEROPLANE STRUCTURAL DESIGN. By T. H. Jones, B.Sc., A.M.I.M.E., and J. D. Frier, A.R.C.Sc., D.I.C.	21	0
AIRCRAFT, MODERN. By Major V. W. Page, Air Corps Reserve, U.S.A.	21	0
"AIRMEN OR NOBLES" Fair Play for Our Airmen. By Rear-Adm. Murray F. Sueter, C.B., R.N., M.P.	25	0
AIRSHIP, THE RIGID. By E. H. Lewitt, B.Sc., M.I.Ae.E.	30	0
LEARNING TO FLY. By F. A. Swoffer, Chief Instructor to the Hampshire Light Aeroplane Club. With a Foreword by Air Vice-Marshal Sir Sefton Branker, K.C.B., A.F.C., Director of Civil Aviation, Air Ministry	4	
PILOT'S "A" LICENCE. Compiled by John F. Leeming, Royal Aero Club Observer for Pilot's Certificates. Second Edition	3	6
<b>MARINE ENGINEERING</b>		
MARINE SCREW PROPELLERS, DETAIL DESIGN OF. By Douglas H. Jackson, M.I.Mar.E., A.M.I.N.A.	6	0
<b>PHOTOGRAPHY, Etc.</b>		
AMATEUR CINEMATOGRAPHY. By Capt. O. Wheeler, F.R.P.S.	6	0
CAMERA LENSES. By A. W. Lockett	2	6
COLOUR PHOTOGRAPHY. By Capt. O. Wheeler, F.R.P.S.	12	6
COMMERCIAL PHOTOGRAPHY. By D. Charles	5	0
COMPLETE PRESS PHOTOGRAPHER, THE. By Bell R. Bell	6	0
LENS WORK FOR AMATEURS. By H. Orford. Fourth Edition	3	6
PHOTOGRAPHIC CHEMICALS AND CHEMISTRY. By T. L. J. Bentley and J. Southworth	3	6
PHOTOGRAPHY AS A BUSINESS. By A. G. Willis	5	0

## 12 PITMAN'S TECHNICAL BOOKS

	s. d
RETOUCHING AND FINISHING FOR PHOTOGRAPHERS. By J. S. Adamson . . . . .	4 0

### ASTRONOMY

ASTRONOMY, PICTORIAL. By G. F. Chambers, F R A S . . . . .	2 6
ASTRONOMY FOR EVERYBODY. By Professor Simon Newcomb, LL.D. With an Introduction by Sir Robert Ball . . . . .	5 0
GREAT ASTRONOMERS. By Sir Robert Ball, D.Sc., LL.D., F.R.S. . . . .	5 0
HIGH HEAVENS, IN THE. By Sir Robert Ball . . . . .	5 0
ROTATION OF THE EARTH, PLANETS, ETC., THE CAUSE OF THE. By Samuel Shields . . . . .	10 6
STARRY REALMS, IN. By Sir Robert Ball, D.Sc., LL.D., F.R.S . . . . .	5 0

### ILLUMINATING ENGINEERING

MODERN ILLUMINANTS AND ILLUMINATING ENGINEERING. By Leon Gaster and J. S. Dow. Second Edition, Revised and Enlarged . . . . .	25 0
---	------

### MOTOR ENGINEERING

AUTOMOBILE AND AIRCRAFT ENGINES. By A. W. Judge, A R C S, A M I A E . . . . .	30 0
CARBURETTOR HANDBOOK, THE. By E. W. Knott, A M I A E . . . . .	10 6
COIL IGNITION FOR MOTOR-CARS. By C. Sylvester, A M I E E, A M I Mech E. . . . .	10 6
GAS AND <del>Oil</del> ENGINE OPERATION. By J. Okill, M I A E . . . . .	5 0
GAS ENGINE TROUBLES AND INSTALLATION, WITH TROUBLE CHART. By John B. Rathbun, M.E. . . . .	2 6
GAS, OIL, AND PETROL ENGINES. By A. Garrard, Wh Ex . . . . .	6 0
MAGNETO AND ELECTRIC IGNITION. By W. Hibbert, A M I E E . . . . .	3 6
MOTOR TRUCK AND AUTOMOBILE MOTORS AND MECHANISM. By T. H. Russell, A.M., M.E., with numerous Revisions and Extensions by John Rathbun . . . . .	2 6
THORNYCROFT. THE BOOK OF THE. By "Auriga." . . . .	2 6

# PITMAN'S TECHNICAL BOOKS 13

		s	d
MOTOR-CYCLIST'S LIBRARY, THE. Each volume in this series deals with a particular type of motor-cycle from the point of view of the owner-driver			
	Each	2	0
A J S, THE BOOK OF THE By W C Haycraft			
ARIEL, THE BOOK OF THE By G S Davison.			
B.S.A., THE BOOK OF THE By "Waysider."			
Third Edition			
DOUGLAS, THE BOOK OF THE By E. W. Knott.			
Second Edition.			
MOTOR-CYCLING FOR WOMEN By Betty and Naney Debenham, with a Foreword by Major H. R. Watling.			
P. AND M., THE BOOK OF THE By W. C. Haycraft			
RALEIGH HANDBOOK, THE. By "Mentor."			
Second Edition.			
• ROYAL ENFIELD, THE BOOK OF THE By R. E. Ryder.			
RUDGE, THE BOOK OF THE By L. H. Cade.			
TRIUMPH, THE BOOK OF THE. By E. T. Brown.			
VILLIERS ENGINE, THE BOOK OF THE. By Cyril Grange.			
• MOTORIST'S LIBRARY, THE. Each volume in this series deals with a particular make of motor-car from the point of view of the owner-driver. • The functions of the various parts of the car are described in non-technical language, and driving, repairs, legal aspects, insurance, • touring, equipment, etc., all receive attention.			
AUSTIN TWELVE, THE BOOK OF THE. By B. Garbutt and R. Twelvetrees. Illustrated by H. M. Bateman. Second Edition		5	0
STANDARD CAR, THE BOOK OF THE. By "Pioneer"		6	0
CLYNO CAR, THE BOOK OF THE. By E. T. Brown.		3	6
SINGER JUNIOR, THE BOOK OF THE By G. S. Davison		2	6
<b>ELECTRICAL ENGINEERING, Etc.</b>			
ACCUMULATOR CHARGING, MAINTENANCE AND REPAIR. By W. S. Ibbetson.		3	6
ACCUMULATORS, MANAGEMENT OF. By Sir D. Salomons, Bart. Tenth Edition, Revised.		7	6



## 14 PITMAN'S TECHNICAL BOOKS

	<i>s. d.</i>
ALTERNATING CURRENT BRIDGE METHODS OF ELECTRICAL MEASUREMENT. By B. Hague, B.Sc.	15 0
ALTERNATING CURRENT CIRCUIT. By Philip Kemp, M.I.E.E.	2 6
ALTERNATING CURRENT MACHINERY, DESIGN OF. By J. R. Barr, A.M.I.E.E., and R. D. Archibald, B.Sc., A.M.I.C.E., A.M.I.E.E.	30 0
ALTERNATING CURRENT MACHINERY: PAPERS ON THE DESIGN OF. By C. C. Hawkins, M.A., M.I.E.E., S. P. Smith, D.Sc., M.I.E.E., and S. Neville, B.Sc.	21 0
ALTERNATING CURRENT POWER MEASUREMENT. By G. F. Tagg	3 6
ALTERNATING CURRENT WORK. By W. Perren Maycock, M.I.E.E. Second Edition.	10 6
ALTERNATING CURRENTS, THE THEORY AND PRACTICE OF. By A. T. Dover, M.I.E.E.	18 0
ARMATURE WINDING, PRACTICAL DIRECT CURRENT. By L. Wollison	7 6
CONTINUOUS CURRENT DYNAMO DESIGN, ELEMENTARY PRINCIPLES OF. By H. M. Hobart, M.I.C.E., M.I.M.E., M.A.I.E.E.	10 6
CONTINUOUS CURRENT MOTORS AND CONTROL APPARATUS. By W. Perren Maycock, M.I.E.E.	7 6
DEFINITIONS AND FORMULAE FOR STUDENTS—ELECTRICAL. By P. Kemp, M.Sc., M.I.E.E.	6
DIRECT CURRENT ELECTRICAL ENGINEERING, ELEMENTS OF. By H. F. Trewman, M.A., and C. E. Condliffe, B.Sc.	5 0
DIRECT CURRENT ELECTRICAL ENGINEERING, PRINCIPLES OF. By James R. Barr, A.M.I.E.E.	15 0
DIRECT CURRENT DYNAMO AND MOTOR FAULTS. By R. M. Archer	7 6
DIRECT CURRENT MACHINES, PERFORMANCE AND DESIGN OF. By A. E. Clayton, D.Sc., M.I.E.E.	16 0
DYNAMO, THE. Its Theory, Design and Manufacture. By C. C. Hawkins, M.A., M.I.E.E. In three volumes Sixth Edition—	
Vol. I.	21 0
Vol. II.	15 0
Vol. III.	30 0
DYNAMO, HOW TO MANAGE THE. By A. E. Bottone, Sixth Edition, Revised and Enlarged	2 0

# PITMAN'S TECHNICAL BOOKS 15

	s	d.
ELECTRIC BELLS AND ALL ABOUT THEM By S. R. Bottone. Eighth Edition, thoroughly revised by C. Sylvester, A.M.I.E.E. . . . .	3	6
ELECTRIC CIRCUIT THEORY AND CALCULATIONS By W. Perren Maycock, M.I.E.E. Third Edition. Revised by Philip Kemp, M.Sc., M.I.E.E., A.A.I.E.E. . . . .	10	6
ELECTRIC LIGHT FITTING, PRACTICAL By F. C. Allsop. Tenth Edition Revised and Enlarged. . . . .	7	6
ELECTRIC LIGHTING AND POWER DISTRIBUTION. By W. Perren Maycock, M.I.E.E. Ninth Edition, thoroughly Revised and Enlarged . . . . .		
Vol. I. . . . .	10	6
Vol. II. . . . .	10	6
ELECTRIC LIGHTING IN FACTORIES AND WORKSHOPS. By Leon Gaster and J. S. Dow . . . . .	6	
ELECTRIC LIGHTING IN THE HOME. By Leon Gaster . . . . .	6	
ELECTRIC MOTORS AND CONTROL SYSTEMS By A. T. Dover, M.I.E.E., A.Amer.I.E.E. . . . .	15	0
ELECTRIC MOTORS (DIRECT CURRENT). THEIR THEORY AND CONSTRUCTION By H. M. Hobart, M.I.E.E., M.Inst.C.E., M.Amer.I.E.E. Third Edition, thoroughly Revised . . . . .	15	0
ELECTRIC MOTORS (POLYPHASE): THEIR THEORY AND CONSTRUCTION. By H. M. Hobart, M.Inst.C.E., M.I.E.E., M.Amer.I.E.E. Third Edition, thoroughly Revised. . . . .	15	0
ELECTRIC MOTORS FOR CONTINUOUS AND ALTERNATING CURRENTS, A SMALL BOOK ON By W. Perren Maycock, M.I.E.E. . . . .	6	0
ELECTRIC TRACTION. By A. T. Dover, M.I.E.E., Assoc.Amer.I.E.E. Second Edition . . . . .	21	0
ELECTRIC WIRING DIAGRAMS. By W. Perren Maycock, M.I.E.E. . . . .	5	0
ELECTRIC WIRING, FITTINGS, SWITCHES, AND LAMPS. By W. Perren Maycock, M.I.E.E. Sixth Edition, Revised, by Philip Kemp, M.Sc., M.I.E.E. . . . .	10	6
ELECTRIC WIRING TABLES By W. Perren Maycock, M.I.E.E., and F. C. Raphael, M.I.E.E. Fifth Edition . . . . .	3	6
ELECTRICAL CONDENSERS By Philip R. Coursey, B.Sc., F.Inst.P., A.M.I.E.E. . . . .	37	6
ELECTRICAL EDUCATOR. By J. A. Fleming, M.A., D.Sc., F.R.S. In two volumes . . . . .	63	0

		s. d.
ELECTRICAL ENGINEERING, CLASSIFIED EXAMPLES IN By S Gordon Monk, B Sc (Eng ), A M I.E.E.		
In two parts—		
Vol I DIRECT CURRENT . . . . .	2	6
Vol II. ALTERNATING CURRENT . . . . .	3	6
ELECTRICAL ENGINEERING, ELEMENTARY By O R Randall, Ph.D , B Sc., Wh Ex . . . . .	5	0
ELECTRICAL ENGINEER'S POCKET BOOK, WHIT- TAKER'S. Originated by Kenelm Edgcombe, M I E E., A M I C E Sixth Edition Edited by R E. Neale, B Sc (Hons ), A C G I , A M I E.E.	10	6
ELECTRICAL INSTRUMENTS IN THEORY AND PRACTICE By W H. F. Murdoch, B Sc., and U A Oschwald, B A. . . . .	12	6
ELECTRICAL INSTRUMENT MAKING FOR AMATEURS. By S R Bottone. Ninth Edition . . . . .	6	0
ELECTRICAL INSULATING MATERIALS By A Monk- house, Junr , M.I.E.E , A M I Mech E. . . . .	21	0
ELECTRICAL GUIDES, HAWKINS'. Each book in pocket size . . . . .	5	0
No 1 Electricity, Magnetism, Induction, Experiments, Dynamos, Armatures, Windings.		
„ 2. Management of Dynamos, Motors, Instruments, Testing		
„ 3 Wiring and Distribution Systems, Storage Batteries		
„ 4 Alternating Currents and Alternators.		
„ 5. A.C. Motors, Transformers, Converters, Rectifiers.		
„ 6. A.C. Systems, Circuit Breakers, Measuring Instruments.		
„ 7. A.C. Wiring, Power Stations, Tele- phone Work . . . . .		
„ 8. Telegraph, Wireless, Bells, Lighting.		
„ 9. Railways, Motion Pictures, Automo- biles, Ignition.		
„ 10. Modern Applications of Electricity. Reference Index.		
ELECTRICAL MACHINES, PRACTICAL TESTING OF. By L. Oulton, A M I E E., and N. J. Wilson, M.I.E.E. Second Edition . . . . .	6	0

# PITMAN'S TECHNICAL BOOKS 17

ELECTRICAL TECHNOLOGY By H. Cotton, M.B.E., M.Sc. A.M.I.E.E. . . . .	12	6
ELECTRICAL TERMS, A DICTIONARY OF By S. R. Roget, M.A., A.M.Inst.C.E., A.M.I.E.E. . . . .	7	6
ELECTRICAL TRANSMISSION AND DISTRIBUTION. Edited by R. O. Kapp, B.Sc., Chartered Electrical Engineer		
I. OVERHEAD TRANSMISSION LINES . . . . .	6	0
II. POWER CABLES . . . . .	6	0
III. SWITCHGEAR Part I . . . . .	6	0
IV. SWITCHGEAR Part II . . . . .	6	0
V. SUB-STATION WORK Part I . . . . .	6	0
VI. SUB-STATION WORK Part II . . . . .	6	0
VII. INSTRUMENTS AND METERS . . . . .	6	0
VIII. AUXILIARY PLANT . . . . .	3	0
ELECTRO-MOTORS HOW MADE AND HOW USED By S. R. Bottone Seventh Edition Revised by C. Sylvester, A.M.I.E.E. . . . .	4	6
ELECTRO-TECHNICS, ELEMENTS OF By A. P. Young O.B.E., M.I.E.E. . . . .	5	0
ENGINEERING EDUCATOR, PITMAN'S Edited by W. J. Kearton, M.Eng., A.M.I.Mech.E., A.M. Inst.N.A. In three volumes . . . . .	63	0
INDUCTION COILS By G. E. Bonney, Fifth Edition, thoroughly Revised . . . . .	6	0
INDUCTION COIL, THEORY OF THE. By E. Taylor- Jones, D.Sc., F.Inst.P. . . . .	12	6
INDUCTION MOTOR, THE. By H. Vickers, Ph.D., M.Eng. . . . .	21	0
KINEMATOGRAPHY PROJECTION A GUIDE TO. By Colin H. Bennett, F.C.S., F.R.P.S. . . . .	10	6
MERCURY-ARC RECTIFIERS AND MERCURY-VAPOUR LAMPS. By J. A. Fleming, M.A., D.Sc., F.R.S. . . . .	6	0
OSCILLOGRAPHS. By J. T. Irwin, M.I.E.E. . . . .	7	6
POWER STATION EFFICIENCY CONTROL. By John Bruce, A.M.I.E.E. . . . .	12	6
POWER WIRING DIAGRAMS By A. T. Dover, M.I.E.E., A.Amer.I.E.E. Second Edition, Revised . . . . .	6	0
PRACTICAL PRIMARY CELLS By A. Mortimer Codd, F.Ph.S. . . . .	5	0

## 18 PITMAN'S TECHNICAL BOOKS

	s.	d.
RAILWAY ELECTRIFICATION. By H. F. Trewman, A.M.I.E.E. . . . .	21	0
STEAM TURBO-ALTERNATOR, THE. By L. C. Grant, A.M.I.E.E. . . . .	15	0
STORAGE BATTERIES: THEORY, MANUFACTURE, CARE, AND APPLICATION. By M. Arendt, F.E.E. . . . .	18	0
STORAGE BATTERY PRACTICE. By R. Rankin, B.Sc., M.I.E.E. . . . .	7	6
TRANSFORMERS FOR SINGLE AND MULTIPHASE CURRENTS. By Dr. Gisbert Kapp, M.Inst.C.E., M.I.E.E. Third Edition, Revised by R. O. Kapp, B.Sc. . . . .	15	0

### TELEGRAPHY, TELEPHONY, AND WIRELESS

ALL EUROPE "THREE," THE. By C. M. R. Balbi, A.M.I.E.E., A.C.G.I. . . . .	6	0
BAUDOT PRINTING TELEGRAPH SYSTEM. By H. W. Pendry. Second Edition . . . . .	6	0
CABLE AND WIRELESS COMMUNICATIONS OF THE WORLD, THE. By F. J. Brown, C.B., C.B.E., M.A., B.Sc. (Lond.) . . . . .	7	6
CRYSTAL AND ONE-VALVE CIRCUITS, SUCCESSFUL. By J. H. Watkins . . . . .	3	6
LOUD SPEAKERS. By C. M. R. Balbi, with a Foreword by Professor G. W. O. Howe, D.Sc., M.I.E.E., A.M.I.E.E., A.C.G.I. . . . .	3	6
RADIO COMMUNICATION, MODERN. By J. H. Reynier. Second Edition . . . . .	5	0
RADIO YEAR BOOK, PITMAN'S. Published annually in December . . . . .	1	6
TELEGRAPHY. By T. E. Herbert, M.I.E.E. Fourth Edition . . . . .	18	0
TELEGRAPHY, ELEMENTARY. By H. W. Pendry. Second Edition, Revised . . . . .	7	6
TELEPHONE HANDBOOK AND GUIDE TO THE TELEPHONIC EXCHANGE, PRACTICAL. By Joseph Poole, A.M.I.E.E. (Wh.Sc.). Seventh Edition . . . . .	18	0
TELEPHONY. By T. E. Herbert, M.I.E.E. . . . .	18	0
TELEPHONY SIMPLIFIED, AUTOMATIC. By C. W. Brown, A.M.I.E.E., <i>Engineer-in-Chief's Department, G.P.O., London</i> . . . . .	6	0

# PITMAN'S TECHNICAL BOOKS 19

	<i>s d.</i>
TELEPHONY, THE CALL INDICATOR SYSTEM IN AUTOMATIC By A G Freestone, <i>of the Automatic Training School, G.P.O., London</i> . . . . .	6 0
TELEPHONY, THE DIRECTOR SYSTEM OF AUTOMATIC. By W. E. Hudson, B.Sc. Hons. (London), Whit. Sch., A.C.G.I. . . . .	5 0
WIRELESS MANUAL, THE By Capt J. Frost . . . . .	5 0
WIRELESS TELEGRAPHY AND TELEPHONY, INTRO- DUCTION TO, By Prof. J. A. Fleming . . . . .	3 6

## MATHEMATICS AND CALCULATIONS FOR ENGINEERS

ALGEBRA, COMMON-SENSE FOR JUNIORS By F. F. Potter, M.A., B.Sc., and J. W. Rogers, M.Sc. . .	3 0
With Answers . . . . .	3 6
ALGEBRA, TEST PAPERS IN By A. F. Donkin, M.A. . .	2 0
With Answers . . . . .	2 6
With Answers and Points Essential to Answers . .	3 6
ALTERNATING CURRENTS, ARITHMETIC OF By E. H. Crapper, M.I.E.E. . . . .	4 6
CALCULUS FOR ENGINEERING STUDENTS By John Stoney, B.Sc., A.M.I.Mech.E. . . . .	3 6
DEFINITIONS AND FORMULAE FOR STUDENTS-- PRACTICAL MATHEMATICS By L. Tott, M.Sc. . .	0 6
ELECTRICAL ENGINEERING, WHITAKER'S ARITH- METIC OF Third Edition, Revised and Enlarged. . .	3 6
ELECTRICAL MEASURING INSTRUMENTS, Com- mercial By R. M. Archer, B.Sc. (Lond.), . A.R.C.Sc., M.I.E.E. . . . .	10 6
GEOMETRY, ELEMENTS OF PRACTICAL PLANE. By P. W. Scott . . . . .	2 6
Also in two parts . . . . . Each	1 0
GEOMETRY, TEST PAPERS IN By W. E. Paterson, M.A., B.Sc. . . . .	2 0
Points Essential to Answers, Is. In one book . .	3 0
GRAPHIC STATICS, ELEMENTARY By J. T. Wight, A.M.I.Mech.E. . . . .	5 0
KILOGRAMS INTO AVOIRDUPOIS, TABLE FOR THE CONVERSION OF. Compiled by Redvers Elder On paper . . . . .	1 0
LOGARITHMS FOR BEGINNERS. By C. N. Pickworth, Wh.Sc. Fourth Edition . . . . .	1 6

## 20      PITMAN'S TECHNICAL BOOKS

	s	d
LOGARITHMS, FIVE FIGURE, AND TRIGONOMETRICAL FUNCTIONS. By W. E. Dommett, A.M.I.A.E., and H. C. Hird, A.F.Ae.S. (Reprinted from <i>Mathe- matical Tables</i> ) . . . . .	1	0
MATHEMATICAL TABLES. By W. E. Dommett, A.M.I.A.E., and H. C. Hird, A.F.Ae.S. . . . .	4	6
MATHEMATICS AND DRAWING, PRACTICAL. By Dalton Grange . . . . .	2	6
With Answers . . . . .	3	0
MATHEMATICS, ENGINEERING APPLICATION OF. By W. C. Bicklev, M.Sc. . . . .	5	0
MATHEMATICS, EXPERIMENTAL. By G. R. Vign, B.Sc. Book I, with Answers . . . . .	1	4
Book II, with Answers. . . . .	1	4
MATHEMATICS FOR TECHNICAL STUDENTS. By G. E. Hall . . . . .	5	0
MATHEMATICS, INDUSTRIAL (PRELIMINARY). By G. W. Stringfellow . . . . .	2	0
With Answers . . . . .	2	6
MATHEMATICS, INTRODUCTORY. By J. E. Rowe, 4th D. . . . .	10	6
MEASURING AND MANURING LAND, AND THATCHERS' WORK, TABLES FOR. By J. Cullyer. Twentieth Impression . . . . .	3	0
MECHANICAL TABLES. By J. Foden . . . . .	2	0
MECHANICAL ENGINEERING DETAIL TABLES. By John P. Ross. . . . .	7	6
METALWORKER'S PRACTICAL CALCULATOR, THE By J. Matheson . . . . .	2	0
METRIC AND BRITISH SYSTEM OF WEIGHTS, MEA- SURES, AND COINAGE. By Dr. F. Mollwo Perkin . . . . .	3	6
METRIC CONVERSION TABLES. By W. E. Dommett, A.M.I.A.E. . . . .	1	0
METRIC LENGTHS TO FEET AND INCHES, TABLE FOR THE CONVERSION OF. Compiled by Redvers Elder. On paper . . . . .	1	0
On cloth, varnished . . . . .	2	0
MINING MATHEMATICS (PRELIMINARY). By George W. Stringfellow . . . . .	1	6
With Answers . . . . .	2	0
QUANTITIES AND QUANTITY TAKING. By W. E. Davis. Sixth Edition . . . . .	6	0

# PITMAN'S TECHNICAL BOOKS 21

	s.	d.
REINFORCED CONCRETE MEMBERS, SIMPLIFIED METHODS OF CALCULATING. By W. N. Twelves, M.I.M.E., A.M.I.E.E. Second Edition, Revised and Enlarged . . . . .	5	0
RUSSIAN WEIGHTS AND MEASURES, WITH THEIR BRITISH AND METRIC EQUIVALENTS, TABLES OF. By Redvers Elder . . . . .	2	6
SLIDE RULE, THE. By C. N. Pickworth, Wh.Sc. Seventeenth Edition, Revised . . . . .	3	6
SLIDE RULE, ITS OPERATIONS; AND DIGIT RULES, THE. By A. Lovat Higgins, A.M.Inst. C.E. . . . .		6
STEEL'S TABLES. Compiled by Joseph Steel . . . . .	3	6
TELEGRAPHY AND TELEPHONY, ARITHMETIC OF. By T. E. Herbert, M.I.E.E., and R. G. de Wardt . . . . .	5	0
TEXTILE CALCULATIONS. By J. H. Whitwam, B.Sc. . . . .	25	0
TRIGONOMETRY FOR ENGINEERS, A PRIMER OF. By W. G. Dunkley, B.Sc. (Hons) . . . . .	5	0
TRIGONOMETRY FOR NAVIGATING OFFICERS. By W. Percy Winter, B.Sc. (Hon.), Lond . . . . .	10	6
TRIGONOMETRY, PRACTICAL. By Henry Adams, M.I.C.E., M.I.M.E., F.S.I. Third Edition, Revised and Enlarged . . . . .	5	0
VENTILATION, PUMPING, AND HAULAGE, MATHEMATICS OF. By F. Birks . . . . .	5	0
WORKSHOP ARITHMETIC, FIRST STEPS IN. By H. P. Green . . . . .	1	0

## MISCELLANEOUS TECHNICAL BOOKS

BREWING AND MALTING. By J. Ross Mackenzie, F.C.S., F.R.M.S. Second Edition . . . . .	8	6
CERAMIC INDUSTRIES POCKET BOOK. By A. B. Searle . . . . .	8	6
ENGINEERING ECONOMICS. By T. H. Burnham, B.Sc. Hons. (Lond.), B.Com. (Lond.), A.M.I. Mech.E. . . . .	10	6
ENGINEERING INQUIRIES, DATA FOR. By J. C. Connan, B.Sc., A.M.I.E.E., O.B.E. . . . .	12	6
ESTIMATING. By T. H. Hargrave . . . . .	7	6
GLUE AND GELATINE. By P. I. Smith. . . . .	8	6
LIGHTNING CONDUCTORS AND LIGHTNING GUARDS. By Sir Oliver J. Lodge, F.R.S., LL.D., D.Sc., M.I.E.E. . . . .	15	0



## 22 PITMAN'S TECHNICAL BOOKS

	s	d.
MUSIC ENGRAVING AND PRINTING. By Wm. Gamble	21	0
PETROLEUM. By Albert Lidgett, <i>Editor of the</i> <i>"Petroleum Times"</i> Third Edition . . . . .	5	0
PRINTING By H. A. Maddox . . . . .	5	0
REFRACTORIES FOR FURNACES, CRUCIBLES, ETC By A. B. Searle . . . . .	5	0
REFRIGERATION, MECHANICAL By Hal Williams, M.I. Mech.E., M.I.E.E., M.I. Struct. E. . . . .	20	0
SEED TESTING. By J. Stewart Remington . . . . .	10	6

### TECHNICAL DICTIONARY OF ENGINEERING AND INDUSTRIAL SCIENCE IN SEVEN LANGUAGES: ENGLISH, FRENCH, SPANISH, ITALIAN, PORTUGUESE, RUSSIAN, AND GERMAN.

In four vols., £8 8s. net complete

Compiled by Ernest Slater, M.I.E.E., M.I. Mech.E., in  
collaboration with leading authorities

### PITMAN'S TECHNICAL PRIMERS

Each in foolscap 8vo, cloth, about 120 pp., illustrated 2 6

In each book of the series the fundamental principles of some subdivision of technology are treated in a practical manner, providing the student with a handy survey of the particular branch of technology with which he is concerned. They should prove invaluable to the busy practical man who has not the time for more elaborate treatises.

ABRASIVE MATERIALS. By A. B. Searle.

A.C. PROTECTIVE SYSTEMS AND GEARS. By J. Henderson, B.Sc., M.C., and C. W. Marshall, B.Sc., A.M.I.E.E.

BELTS FOR POWER TRANSMISSION. By W. G. Dunkley, B.Sc. (Hons.).

BOILER INSPECTION AND MAINTENANCE. By R. Clayton.

CAPSTAN AND AUTOMATIC LATHES. By Philip Gates.

CENTRAL STATIONS, MODERN. By C. W. Marshall, B.Sc., A.M.I.E.E.

COAL CUTTING MACHINERY, LONGWALL. By G. F. F. Eagar, M.I.Min.E.

PITMAN'S TECHNICAL PRIMERS—*contd*

CONTINUOUS CURRENT ARMATURE WINDING.

By F. M. Denton, A.C.G.I., A.Amer.I.E.E.

CONTINUOUS CURRENT MACHINES, THE TESTING  
OF. By Charles F. Smith, D.Sc., M.I.E.E.,  
A.M.I.C.E.

COTTON SPINNING MACHINERY AND ITS USES.

By Wm. Scott Taggart, M.I.Mech.E.

DIESEL ENGINE, THE. By A. Orton

DROP FORGING AND DROP STAMPING. By H.  
Hayes

ELECTRIC CABLES. By F. W. Mann, A.M.I.E.E.

ELECTRIC CRANES AND HAULING MACHINES. By  
F. E. Chilton, A.M.I.E.E.

ELECTRIC FURNACE, THE. By Frank J. Moffett,  
B.A., M.I.E.E., M.Cons.E.

ELECTRIC MOTORS, SMALL. By E. T. Panton,  
B.Sc., A.M.I.E.E.

ELECTRIC POWER SYSTEMS. By Capt. W. T.  
Taylor, M.Inst.C.E., M.I.Mech.E.

ELECTRICAL INSULATION. By W. S. Flieger,  
A.M.I.E.E.

ELECTRICAL TRANSMISSION OF ENERGY. By W.  
M. Thornton, O.B.E., D.Sc., M.I.E.E.

ELECTRICITY IN AGRICULTURE. By A. H. Allen,  
M.I.E.E.

ELECTRICITY IN STEEL WORKS. By Wm.  
McFarlane, B.Sc.

ELECTRIFICATION OF RAILWAYS, THE. By H. F.  
Trewman, M.A.

ELECTRO-DEPOSITION OF COPPER, THE, And its  
Industrial Applications. By Claude W. Denny,  
A.M.I.E.E.

EXPLOSIVES, MANUFACTURE AND USES OF. By  
R. C. Farmer, O.B.E., D.Sc., Ph.D.

FILTRATION. By T. R. Wollaston, M.I.Mech.E.

FOUNDRYWORK. By Ben Shaw and James  
Edgar.

GRINDING MACHINES AND THEIR USES. By Thos.  
R. Shaw, M.I.Mech.E.

HOUSE DECORATIONS AND REPAIRS. By Wm.  
Prebble.

## 24 PITMAN'S TECHNICAL BOOKS

### PITMAN'S TECHNICAL PRIMERS—*contd.*

- |  |              |
|--|--------------|
|  | s. d.<br>2 6 |
| HYDRO-ELECTRIC DEVELOPMENT By J. W. Meates, F.R.A.S., M.Inst.C.E., M.I.E.E., M.Am.I.F.E. |              |
| ILLUMINATING ENGINEERING, THE ELEMENTS OF. By A. P. Trotter, M.I.E.E.                    |              |
| INDUSTRIAL AND POWER ALCOHOL By R. C. Farmer, O.B.E., D.Sc., Ph.D., F.I.C.               |              |
| INDUSTRIAL ELECTRIC HEATING By J. W. Beauchamp, M.I.E.E.                                 |              |
| INDUSTRIAL MOTOR CONTROL By A. T. Dover, M.I.E.E.  |              |
| INDUSTRIAL NITROGEN By P. H. S. Kempton, B.Sc. (Hons.), A.R.C.Sc.                        |              |
| KINEMATOGRAPH STUDIO TECHNIQUE By L. C. Macbean  |              |
| LUBRICANTS AND LUBRICATION By J. H. Hyde.  |              |
| MECHANICAL HANDLING OF GOODS, THE By C. H. Woodfield, M.I.Mech.E.                        |              |
| MECHANICAL STOKING. By D. Brownlie, B.Sc., A.M.I.M.E. (Double vol., price 5s. net.)      |              |
| METALLURGY OF IRON AND STEEL Based on Notes by Sir Robert Hadfield                       |              |
| MUNICIPAL ENGINEERING By H. Percy Boulnois, M.Inst.C.E., F.R.San.Inst., F.Inst.S.E.      |              |
| OILS, PIGMENTS, PAINTS, AND VARNISHES By R. H. Love.                                     |              |
| PATTERNMAKING. By Ben Shaw and James Edgar.  |              |
| PETROL CARS AND LORRIES. By F. Heap  |              |
| PHOTOGRAPHIC TECHNIQUE By L. J. Albert, F.R.P.S.   |              |
| PNEUMATIC CONVEYING By E. G. Phillips, M.I.E.E., A.M.I.Mech.E.                           |              |
| POWER FACTOR CORRECTION By A. E. Clayton, B.Sc. (Eng.) Lond., A.K.C., A.M.I.E.E.         |              |
| RADIOACTIVITY AND RADIOACTIVE SUBSTANCES. By J. Chadwick, M.Sc.                          |              |
| RAILWAY SIGNALLING. AUTOMATIC. By F. Raynar Wilson.                                      |              |
| RAILWAY SIGNALLING: MECHANICAL. By F. Raynar Wilson.                                     |              |
| SEWERS AND SEWERAGE. By H. Gilbert Whyatt, M.I.C.E.                                      |              |

PITMAN'S TECHNICAL PRIMERS—*contd.*

SPARKING PLUGS By A P Young and H Warren.

STEAM ENGINE VALVES AND VALVE GEARS By  
E. L. Ahrons, M I Mech E, M I Loco E.STEAM LOCOMOTIVE, THE By E. L. Ahrons,  
M I Mech E, M I Loco E.STEAM LOCOMOTIVE CONSTRUCTION AND MAIN-  
TENANCE By E. L. Ahrons, M I Mech. E.,  
M I Loco E.STEELS, SPECIAL Based on Notes by Sir Robert  
Hadfield, Bart., compiled by T. H. Burnham,  
B Sc. (Double vol., price 5s.)

STEELWORK, STRUCTURAL By Wm. H. Black.

STREETS, ROADS, AND PAVEMENTS. By H. Gilbert  
Whyatt, M Inst C E, M R San E.SWITCHBOARDS, HIGH TENSION. By Henry E.  
Poole, B Sc. (Hons.), Lond., A C G I,  
A M I E E.SWITCHGEAR, HIGH TENSION By Henry E. Poole,  
B Sc. (Hons.), A C G I, A M I E E.SWITCHING AND SWITCHGEAR By Henry E.  
Poole, B Sc. (Hons.), A C G I, A M I E E.TELEPHONES, AUTOMATIC By F. A. Ellison,  
B Sc., A M I E E. (Double vol., price 5s.)TIDAL POWER By A. M. A. Struben, O B E,  
A. M. Inst C E.TOOL AND MACHINE SETTING. For Milling,  
Drilling, Tapping, Boring, Grinding, and Press  
Work. By Philip Gates.TOWN GAS MANUFACTURE. By Ralph Staley,  
M.C.TRACTION MOTOR CONTROL By A. T. Dover,  
M. I. E. E.TRANSFORMERS AND ALTERNATING CURRENT  
MACHINES, THE TESTING OF. By Charles F.  
Smith, D Sc., A M Inst C E, Wh Sc.TRANSFORMERS, HIGH VOLTAGE POWER. By Wm.  
T. Taylor, M Inst C E, M I E E.TRANSFORMERS, SMALL SINGLE-PHASE. By Edgar  
T. Pantton, B Sc. Eng., Hons. (Lond.),  
A. M. I. E. E.WATER POWER ENGINEERING. By F. F. Fergusson,  
A. M. Inst. C. E.

PITMAN'S TECHNICAL PRIMERS— <i>contd.</i>	s.	d.
WIRELESS TELEGRAPHY, CONTINUOUS WAVE. By B. E. G. Mittell, A.M.I.E.E.	2	6
WIRELESS TELEGRAPHY, DIRECTIVE. Direction and Position Finding, etc. By L. H. Walter, M.A. (Cantab.), A.M.I.E.E.		
X-RAYS, INDUSTRIAL APPLICATION OF By P. H. S. Kempton, B.Sc. (Hons).		

### COMMON COMMODITIES AND INDUSTRIES SERIES

Each book is crown 8vo, cloth, with many illustrations, etc.

In each of the handbooks in this series a particular product or industry is treated by an expert writer and practical man of business

ACIDS, ALKALIS, AND SALTS By G. H. J. Adlam,  
M.A., B.Sc., F.C.S.

ALCOHOL IN COMMERCE AND INDUSTRY By C.  
Simmonds, O.B.E., B.Sc., F.I.C., F.C.S.

ALUMINIUM Its Manufacture, Manipulation, and  
Marketing By George Mortimer, M.Inst.Met

ANTHRACITE. By A. Leonard Summers

ASBESTOS. By A. Leonard Summers

BOOKBINDING CRAFT AND INDUSTRY, THE By  
T. Harrison.

BOOKS: FROM THE MS. TO THE BOOKSELLER. By  
J. L. Young.

BOOT AND SHOE INDUSTRY, THE By J. S. Harding.

BREAD AND BREAD BAKING. By John Stewart.

BRUSHMAKING, THE. By Wm. Kiddier.

BUTTER AND CHEESE. By C. W. Walker Tisdale,  
F.C.S., and Jean Jones, B.D.F.D., N.D.D.

BUTTON INDUSTRY, THE By W. Unite Jones.

CARPETS. By Reginald S. Brinton.

CLAYS AND CLAY PRODUCTS. By Alfred B. Searle.

CLOCKS AND WATCHES By G. L. Overton.

CLOTHS AND THE CLOTH TRADE. By J. A. Hunter.

CLOTHING INDUSTRY, THE By B. W. Poole

COAL. Its Origin, Method of Working, and Pre-  
paration for the Market By Francis H. Wilson,

M.Inst.M.E.

COAL TAR By A. R. Warnes, F.C.S., A.I.Mech.E.

COMMON COMMODITIES AND INDUSTRIES SERIES s. d.  
3 0

—*contd.*

COCOA AND CHOCOLATE INDUSTRY, THE By A W. Knapp, B.Sc., F.I.C.

COFFEE From Grower to Consumer By B. B. Keable

COLD STORAGE AND ICE MAKING By B. H. Springett

CONCRETE AND REINFORCED CONCRETE By W. Noble Twiss, M.I.M.E., A.M.I.C.E.

COPPER From the Ore to the Metal By H. K. Picard, M.I.M.E. and Met.

CORDAGE AND CORDAGE HEMP AND FIBRES By T. Woodhouse and P. Kilgour

CORN TRADE, THE BRITISH By A. Barker

COTTON From the Raw Material to the Finished Product By R. J. Peake

COTTON SPINNING By A. S. Wade

CYCLE INDUSTRY, THE By W. Grew

DRUGS IN COMMERCE By J. Humphrey, Ph.C., F.J.I.

DYES AND THEIR APPLICATION TO TEXTILE FABRICS By A. J. Hall, B.Sc., F.I.C., F.C.S.

ELECTRIC LAMP INDUSTRY, THE By G. Archiffe Percival

ELECTRICITY By R. E. Neale, B.Sc. (Hons.)

ENGRAVING By T. W. Lascelles

EXPLOSIVES, MODERN By S. I. Levy, B.A., B.Sc., F.I.C.

FERTILIZERS By H. Cave

FILM INDUSTRY, THE By Davidson Bonighey

FISHING INDUSTRY, THE By W. E. Gibbs, D.Sc.

FURNITURE By H. E. Binstead. Second Edition.

FURS AND THE FUR TRADE By J. C. Sachs

GAS AND GAS MAKING By W. H. Y. Webber, C.E.

GLASS AND GLASS MANUFACTURE By P. Mason, *Honours and Medallist in Glass Manufacture.*

GLOVES AND THE GLOVE TRADE By B. E. Ellis

GOLD By Benjamin White

GUMS AND RESINS Their Occurrence, Properties, and Uses By Ernest J. Parry, B.Sc., F.I.C., F.C.S.

## 28 PITMAN'S TECHNICAL BOOKS

	<i>s.</i>	<i>d</i>
COMMON COMMODITIES AND INDUSTRIES SERIES	3	0
<i>—contd</i>		
INCANDESCENT LIGHTING By S I Levy, B.A., B.Sc., F.I.C.		
INK By C. Ainsworth Mitchell, M.A., F.I.C.		
INTERNAL COMBUSTION ENGINES By J. Okill, M.I.A.E.		
IRON AND STEEL Their Production and Manu- facture. By C. Hood.		
IRON-FOUNDING. By B. Whiteley.		
JUTE INDUSTRY, THE By T. Woodhouse and P. Kilgour.		
KNITTED FABRICS By John Chamberlain and James H. Quilter		
LEAD. Including Lead Pigments. By J. A. Smythe, Ph.D., D.Sc.		
LEATHER From the Raw Material to the Finished Product. By K. J. Adcock.		
LINEN From the Field to the Finished Product By Alfred S. Moore		
LOCKS AND LOCK MAKING By F. J. Butter.		
MATCH INDUSTRY, THE. By W. H. Dixon		
MEAT INDUSTRY, THE By Walter Wood		
MOTOR BOATS By Major F. Strickland, M.I.E.E., M.I.M.E.		
MOTOR INDUSTRY, THE. By Horace Wyatt, B.A.		
NICKEL. By F. B. Howard White, B.A.		
OIL POWER By Sidney H. North, A.Inst.P.T.		
OILS Animal, Vegetable, Essential, and Mineral. By C. Ainsworth Mitchell, M.A., F.I.C.		
PAINTS AND VARNISHES. By A. S. Jennings, F.I.B.D.		
PAPER Its History, Sources, and Production. By Harry A. Maddox, <i>Silver Medalist Paper-</i> <i>making</i> Second Edition		
PATENT FUELS By J. A. Greene and F. Mořwo Perkin, C.B.E., Ph.D., F.I.C.		
PEPPUMERY, RAW MATERIALS OF. By E. J. Parry, B.Sc., F.I.C., F.C.S.		
PHOTOGRAPHY. By William Gamble, F.R.P.S.		
PLATINUM METALS. By E. A. Smith, A.R.S.M., M.I.M.M.		
PLAYER PIANO, THE. By D. Miller Wilson.		

COMMON COMMODITIES AND INDUSTRIES SERIES s d  
3 0

--contd

- POTTERY By C J Noke and H J Plant.  
 RICE. By C E Douglas, M I Mech E  
 RUBBER Production and Utilization of the Raw Product By C Beadle and H. P. Stevens, M A, Ph D, F I C  
 SALT. By A F Calvert, F C S  
 SHIPBUILDING AND THE SHIPBUILDING INDUSTRY. By J Mitchell, M I N A  
 SILK Its Production and Manufacture. By Luther Hooper  
 SILVER By Benjamin White  
 SOAP Its Composition, Manufacture, and Properties By William H Simmons, B Sc (Lond), F C S  
 SPONGES By E J J Cresswell  
 STARCH AND STARCH PRODUCTS By H A Auden, D Sc, F C S.  
 STONES AND QUARRIES By J Allen How O B E, B Sc, M Inst Min and Met  
 STRAW HATS By H Inwards  
 SUGAR Cane and Beet By the late Geo. Martineau, C B, and Revised by F C Eastick, M A Fifth Edition  
 SULPHUR AND THE SULPHUR INDUSTRY By Harold A Auden, M Sc, D.Sc, F C S  
 TALKING MACHINES By Ogilvie Mitchell.  
 TEA From Grower to Consumer By A Ibbetson  
 TELEGRAPHY, TELEPHONY, AND WIRELESS By Joseph Poole, A M I E E  
 TEXTILE BLEACHING By Alex B Steven, B Sc (Lond), F I C  
 TIMBER. From the Forest to its Use in Commerce. By W. Bullock. Second Edition.  
 TIN AND THE TIN INDUSTRY By A. H Mundy.  
 TOBACCO From Grower to Smoker By A E. Tanner  
 VELVET AND THE CORDUROY INDUSTRY By J. Herbert Cooke.



## 30 PITMAN'S TECHNICAL BOOKS

COMMON COMMODITIES AND INDUSTRIES SERIES s. d  
3 0  
—*contd.*

WALL-PAPER By G. Whiteley Ward.

WEAVING. By W. P. Crankshaw.

WHEAT AND ITS PRODUCTS By Andrew Millar.

WINE AND THE WINE TRADE By André L. Simon.

WOOL. From the Raw Material to the Finished Product. By J. A. Hunter

WORSTED INDUSTRY, THE By J. Dumville and S. Kershaw. Second Edition

ZINC AND ITS ALLOYS By T. E. Lones, M.A., LL.D., B.Sc.

### PITMAN'S "CRAFT-FOR-ALL" SERIES

Each in crown 8vo, illustrated . . . . . net 2 6

BASKETRY. By Mabel Rosley.

DESIGN AS APPLIED TO ARTS AND CRAFTS. By F. R. Smith

FLOWER MAKING. By Violet Brand.

GESSO. By Idalia B. Littlejohns.

GLOVE MAKING. By I. M. Andrews.

HOME UPHOLSTERY. By M. Dane.

LEATHER WORK. By F. R. Smith

METAL WORK. By A. C. Horth.

PLYWOOD. By W. B. Little.

PRINTS AND PATTERNS. By Idalia B. Littlejohns.

RAFFIA WORK. By Annie L. Begg.

RUG MAKING. By Dorothy Drage.

**PITMAN'S SHORTHAND**  
**INVALUABLE TO ALL BUSINESS AND PROFESSIONAL MEN**

*The following Catalogues will be sent post free, on application—*  
**EDUCATIONAL, COMMERCIAL, SHORTHAND, FOREIGN**  
**LANGUAGE, AND ART**

FROM THE SAME PUBLISHERS

## **DEFINITIONS AND FORMULAE FOR STUDENTS**

THIS series of booklets is intended to provide engineering students with all necessary definitions and formulæ in a convenient form

In four booklets. Each in Pocket Size, about  
32 pp. 6d. net.

### **DEFINITIONS AND FORMULAE FOR STUDENTS—ELECTRICAL**

By PHILIP KEMP, M.Sc., M.I.E.E., *Head of the  
Electrical Engineering Department of the Regent  
Street Polytechnic.*

### **DEFINITIONS AND FORMULAE FOR STUDENTS—HEAT ENGINES**

By ARNOLD RIMMER, B.Eng., *Head of the Mechanical  
Engineering Department, Derby Technical College.*

### **DEFINITIONS AND FORMULAE FOR STUDENTS—APPLIED MECHANICS**

By E. H. LEWITT, B.Sc., A.M.I.Mech.E.

### **DEFINITIONS AND FORMULAE FOR STUDENTS—PRACTICAL MATHEMATICS**

By LOUIS TORT, M.Sc., *Head of the Mathematical  
Department of the Royal Technical College, Salford.*

# PITMAN'S TECHNICAL DICTIONARY

OF  
ENGINEERING AND INDUSTRIAL SCIENCE  
IN SEVEN LANGUAGES  
ENGLISH, FRENCH, SPANISH, ITALIAN  
PORTUGUESE, RUSSIAN, AND GERMAN

*Edited by*

ERNEST SLATER, M.I.E.E., M.I.Mech.E.

*In Collaboration with Leading Authorities*

THE Dictionary is arranged upon the basis of the English version. This means that against every English term will be found the equivalents in the six other languages, together with such annotations as may be necessary to show the exact use of the term in any or all of the languages.

"There is not the slightest doubt that this Dictionary will be the essential and standard book of reference in its sphere. It has been needed for years."—*Electrical Industries*.

"The work should be of the greatest value to all who have to deal with specifications, patents, catalogues, etc.; for use in foreign trade."—*Bankers' Magazine*.

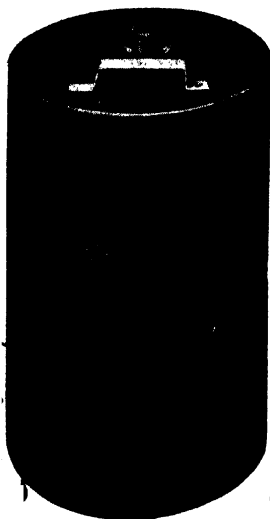
"The work covers extremely well the ground it sets out to cover, and the inclusion of the Portuguese equivalents will be of real value to those who have occasion to make technical translations for Portugal, Brazil, or Portuguese East Africa."—*Nature*.

Complete in four volumes, crown 4to, buckram gilt.  
£8 8s. net.

---

Sir Isaac Pitman & Sons, Ltd., Parker St., Kingsway, W.C.2

# ELECTRICALLY WELDED STEEL DRUMS & KEGS



Absolutely tight &  
of great strength  
and durability

Infinitely superior  
to the ordinary  
riveted or soldered  
package

Made to Railway  
Companies' latest  
specifications

Various sizes of  
Bungs & openings

**WELDED STEEL BARRELS**  
**DRUMS, TANKS, etc.,** FOR ALL PURPOSES

**The Steel Barrel Company, Ltd.**

*Contractors to the War Office, India Office, etc., etc.*

**UXBRIDGE, MIDDLESEX**

Telegrams: "Barrels, Uxbridge"

Telephone: Uxbridge 251 & 252

*By mentioning this book when replying, you will oblige  
Advertiser, Author, and Publishers*

(5398)

**Crimson Sub-Oxide  
of Copper**

**Yellow Oxide of  
Mercury**

**Sulphocyanide of  
Copper**

**Brown or Black  
Copper Oxide**

**&c., &c.**

**JAMES M. BROWN**

**35 SURREY STREET, STRAND**

**LONDON, W.C.2**

SOLE AGENTS,  
"CHARTERED, LONDON"

SOLE AGENTS,  
"CHARTERED, LONDON"

*Works: Stoke-on-Trent*

— FINEST —

# ZINC OXIDE

*Manufactured by*

**KEELING'S OXIDES**

**(1921) LTD.**

**35 SURREY STREET, STRAND**  
— LONDON, W.C.2 —

*Telegrams:*

**"GRAWITHWA, LONDON"**

*Telephones:*

**CITY 2431, CENTRAL 4282**

*By mentioning this book when replying, you will oblige  
Advertiser, Author and Publishers*